MANUAL OF INSTRUCTION

IN

HARD SOLDERING

WITH AN APPENDIX ON THE

REPAIR OF BICYCLE FRAMES;

NOTES ON ALLOYS AND

A CHAPTER ON SOFT SOLDERING.

BY

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CONTENTS.

INTRODUCTION.

CHAPTER I.—UTENSILS AND CHEMICALS.

THE FLAME 8
LAMP 8
CHARCOAL 9
MATS 9
BLOWPIPES 10
WASH-BOTTLE 10
BINDING WIRE 12
BORAX 13
CHEMICALS 14

CHAPTER II.—ALLOYS FOR HARD SOLDERING.

SPELTER 14
SILVER SOLDER 15
GOLD SOLDER 17

CHAPTER III.—OXIDATION.

OXIDATION OF METALS 18
FLUXES 19
ANTI-OXIDIZERS 20

CHAPTER IV.—STRUCTURE OF FLAME.

OXIDATION OF GASES 21
THE CONE 22
OXIDIZING FLAME 22
REDUCING FLAME 23

CHAPTER V.—HEAT.

TRANSMISSION 25
CONDUCTION 26
CAPACITY OF METALS 27
RADIATION 27
APPLICATION 28

Chapter VI.—The Process.

THE WORK TABLE 29
THE JOINT 30
APPLYING SOLDER 30
APPLYING HEAT 31
THE USE OF THE BLOWPIPE 31
MAKING A FERRULE 32
JOINTS 34
TO REPAIR A SPOON 35
DIFFICULTIES 36

Chapter VII.—The Process—Continued.

TO REPAIR A WATCH CASE 37
HARD SOLDERING WITH A FORGE OR HEARTH 40
HARD SOLDERING WITH TONGS 41

Chapter VIII.—Technical Notes.

PRESERVING THIN EDGES 42
SILVERSMITH'S PICKLE 43
RESTORING COLOR TO GOLD 43
CHROMIC ACID 44
STEEL SPRINGS, TO MEND 45
SWEATING METALS TOGETHER 45
RETAINING WORK IN POSITION 46
MAKING JOINTS 46
APPLYING HEAT 47
PREVENTING THE LOSS OF HEAT 48
EFFECT OF SULPHUR, LEAD AND ZINC 49
TO PRESERVE PRECIOUS STONES 50
ANNEALING AND HARDENING 51
BURNT IRON 52
TO HARD SOLDER AFTER SOFT SOLDER 52

Chapter IX.—Properties of Metals.

TABLE OF SPECIFIC GRAVITY 53
TABLE OF TENACITY 53
TABLE OF FUSIBILITY 54
FUSIBILITY OF ALLOYS 54

Appendix. Index.

⁕Introduction.⁕

A knowledge of the uses of heat makes the nation civilized; enables man to progress. Just in proportion as the knowledge of the processes depending upon the laws of heat have become disseminated, so have nations grown in importance and advanced in civilization.

In our age, in construction of forms in metal, heat is indispensable. The fundamental processes of casting, annealing, welding and soldering metals underly the other arts and depend upon scientific research for improvement. The products of these arts, as shown in the tools of the artisan, instruments of the surgeon, engineer, astronomer, and the apparatus of the chemist, add to the facilities for investigating the laws of nature, a knowledge of which in turn enables the maker of implements and manipulator of processes to also improve.

To unite pieces of metal already having solidity and form, in a firm and substantial manner, making the whole as one solid piece, has always been one of the processes most useful to man. Although not particularly hard to acquire, a thorough knowledge of it has been enjoyed by few in comparison with its every day usefulness and importance.

The rapid changes that are taking place in mechanical

engineering cause a demand for men who understand the arts of construction, men who have a scientific knowledge of the laws that underlie their skill, and who are able to adapt the state of the art to new wants. Having no rigid system of apprenticeship in this country, and but few schools where the mechanical arts are taught practically, the young man is often left to accidental resources to acquire a knowledge of the useful arts.

With the rapid development of new inventions comes a class of young men having the genius for mechanical invention who desire to be able to construct the devices for their experiments, but who do not want to serve a term of years at any one trade. Since hard soldering or brazing is often a fundamental process in the construction of models, they are often left to weak or clumsy devices to bridge over a lack of knowledge of that process.

Among the jewelers, gunsmiths, makers of surgical, mathematical, optical and philosophical instruments, watchmakers and occasionally the dentists, it has been handed down from one generation to another, each one teaching it as adapted to his own requirements, so useful is it in nearly all branches of mechanical construction.

Much that is published in this little work may be new only to the beginner, and may not add materially to the skill of the experienced workman in his own department of industry, nevertheless it is well to compare notes, and if only one little point is gained it will be worth to the practitioner the cost of so inexpensive a volume. To the person having use for, and seeking such information as it contains I hope it may prove invaluable. I ask of the apprentice or amateur into whose hands it may fall that they

study it thoroughly, and then use the information gained as a stepping stone to the acquisition of further information and improvement by observation and experiment. Pleasure in work is derived from the ability to do it *well*.

Be thorough, persevering, observing.

CHAPTER I.

UTENSILS AND CHEMICALS.

Any clear flame may be used for hard soldering with a blowpipe. That of illuminating gas is to be preferred if obtainable. Away from cities where gas is common, the alcohol lamp is most used. Several kinds of lamps are now sold that are adapted to the wants of the trade, but if these are not at hand a tinner can soon make one. It should hold at least 4 oz. of alcohol, and have a wick tube attached near the bottom not much less than one-half inch in diameter. The top of the wick tube should be cut off obliquely, the left side, as it sits facing you, being the lowest. The wick, when saturated, should be so tight that. although it may be moved up or down in the tube, it will remain in any position. The wick tube must have a cap fitting snugly, to cover the end of the wick when not in use. The size of the lamp should correspond with the size of the work and amount of heat required. Blast lamps, furnaces and hearths are now sold, a description of which I leave to the manufacturers.

The lamp should never be filled quite full of alcohol, it being liable at any time when in use to become warm, thus expanding the alcohol and causing it to overflow or blow out the wick.

The beginner should form the habit of covering the wick as soon as it is blown out. If left exposed to the air the alcohol evaporates, leaving the water it contains at the end of the wick, rendering it hard to light.

For gas, the Bunsen burner, with blowpipe tube, is to be obtained from dealers in chemical wares.

A few pieces of charcoal should be provided on which to lay the work to be soldered. Select that which is well burned and is not too strong through the grain of the wood. The charcoal made from the softer close grained woods or roots is best, since if it is well burned it is not liable to crack and throw sparks with the first heat. Some pieces of coal will continue to burn when laid away if a spark of fire be left unextinguished. The workman will therefore be careful when leaving his work to examine the coal he has been using, and as a further safeguard to cover the table top with sheet metal or slate, where the coal is laid.

For some kinds of work a mat made of old pieces of binding wire, on which to lay the work, is used. Its advantage is that it presents a uniform surface to lay work on, and in not burning away. Asbestos cloth answers the same purpose. Charcoal, on the other hand, has several useful qualities peculiar to itself. Pins may be stuck into it to retain in position the pieces to be united. It may be cut into shape to fit the work or to hold melted metals. In burning, it unites with the surplus oxygen surrounding the work, and increasing the heat.

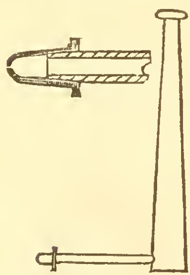
Blowpipe.—Those offered for sale are so cheap and answer the purpose so well that others are not commonly used. They are described as "plain" and "with ball." Some prefer a plain one, and for soft soldering, or jobs requiring but a short blast are advantageous, since they dry out quicker than those with a bulb. For a long continued blast, those with a bulb are preferable, since the chamber

holds for a time the condensed vapor from the breath. If the bulb does not unscrew to empty, and a series of long continued blasts are to be made, after each blast the bulb should be held over the flame until the moisture is expelled.

Brass, if well nickel plated is preferable to silver, by reason of its being a poorer conductor of heat. The tip should be platinum, having an orifice of a size suitable to the work. It is well to have the mouth piece plated with silver or gold, or if the workman likes he may make a ferrule of horn, ivory, silver or gold and put on. It is sometimes convenient to have the mouth piece square, as it can then be held in position by the teeth for a short time if it is necessary to use both hands.

I once made a blowpipe in a few minutes by simply bending a piece of glass tube over the flame of the lamp, to the desired angle, then drawing to a point and breaking off until the aperture was the right size, usually about one-fiftieth of an inch. Its smooth tapering nozzle gave a very nice jet, better than that of any metal one, according to my experience. A form of blowpipe not usual in the trade is described in Eliot and Storer's Chemical Analysis. The construction can be seen from the accompanying Fig. 1. The tip should be drilled out of a solid piece of platinum or brass, and should not be fastened on with a screw.

Fig. 1.



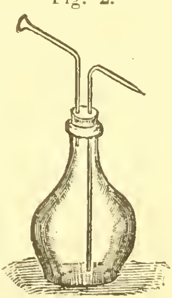
Wash-bottle.—Next to the apparatus for increasing the temperature comes that for reducing it. A fine jet of water is often useful

for cooling portions of the work and for putting out the fire on charcoal. For these purposes I find the chemists' wash bottle very convenient.

To construct one, procure an open mouthed bottle that will hold at least a half pint, a cork to fit, and a piece of quarter inch glass tube, twice as long as the bottle. At about the length of the bottle and two inches more hold the tube over the flame of the lamp, rolling it slowly over in the flame until it becomes red, then pull it out lengthwise until it parts. Break the thread from the end of the measured off piece, leaving a hole large enough to insert an ordinary pin. Ram the hole in the tube full of dry sand and hold in the flame about two inches from the small end, rolling over as before until red hot, then bend to an angle of about 60° or somewhat farther than square.

Cut the tapering point off the other piece with the corner of a file and fill with sand as before. At about two inches from the end, bend to an angle of 120° or not quite square. Cut off the longer end so as to leave it about two and one-half inches long and insert the end in the flame, as also the sharpened end of a slate pencil. When the glass becomes pliable insert the end of the pencil in the hole in the tube, and rolling both while the pencil is gradually pressed to an angle with the tube, spread the end into a flaring mouthpiece.

Fig. 2.



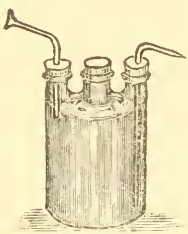
Make two holes in the cork and insert the tubes; the longer end so that it will reach near the bottom of the bottle. See Figures 2 and 3. Insert the other nearly through the cork and leaving the

bent ends in line, cover the surface of the cork with sealing wax.

If the bottle be now filled with water, and the cork inserted, when you blow in the mouthpiece, the pressure of the air on the water will force a stream of water from the nozzle.

A one-half pint three necked Woulff bottle makes a good wash bottle, as shown in Figure 3.

Fig. 3.



A tube is inserted in each of the outer necks while the middle one is used to fill through, and saves the necessity of removing the corks having tubes in, when it is necessary to replenish.

It is also an improvement to make a metal elbow for the discharge pipe, from which the nozzle may be removed to clean. Clear water only should be used in the bottle. Floating particles, if larger than the aperture in the nozzle, are caught there and stop or clog the stream.

Binding Wire.—Get the best annealed iron binding wire. For light work see that it is fine about No. 32, and is not tinned. The tinned wire may be used on steel or brass but should never be used on gold or silver. If no other is convenient, remove the tin by drawing it between pieces of No. 0 emery paper and anneal by drawing it slowly through the flame of the lamp, heating it to a dull red as it passes through. If the work is too heavy for a single wire double and twist the light wire.

Borax. (Sodae Boras—Biborate of Soda.) Buy always the best in the market. It should be well crystalized and in irregular shaped lumps. The surface should not be white or chalky, as that appearance indicates that either the borax or some of its impurities have commenced to oxydize.

It is liable to be adulterated with alum or salt, and sometimes contains sulphate of potash, sulphate of soda or sulphate of magnesia from which it has not been properly purified. Any of them are deleterious. The importance of having borax of good quality is so great in proportion to the amount used, that the difference in price is insignificant. When good is not to be obtained it may sometimes be improved by melting to a glass with the blowpipe flame, then dissolving in water and evaporating the water, thus oxidizing a portion of the impurities.

The useful properties of the borax are that it melts before the solder and flows over the parts to be united, protecting their surfaces and the solder from the oxygen of the air. It also has an affinity for metallic oxides with which it unites, keeping the metallic surfaces clean for the flow of the solder, as will be explained more fully hereafter.

It is sometimes calcined (melted and pulverized) before using.

It is conveniently prepared for use by rubbing on a piece of slate with a drop of water until it forms a paste.

The jeweler should add to the articles mentioned a pair of tweezers, some plaster of Paris, some pieces of black lead, a piece of raw potato or apple. Those who work gold and silver will need some chemical reagents, viz:

Nitric Acid,
Sulphuric Acid,
Bichromate of Potash,
Saltpetre,
Ammonia,
Yellow Ochre, &c.,
the uses of which will be explained in other connections.

CHAPTER II.

ALLOYS FOR HARD SOLDERING.

Every workman should learn to make his own hard solder, since in many instances he can expect success not only by a thorough knowledge of the properties of the materials to be united but also of the metal he proposes to flow on them.

In the department of soldering called *brazing*, spelter solder is used. It is composed of equal parts of copper and zinc. The copper should be put in a crucible and heated to a red heat, with a flux composed of charcoal dust and borax, then add the zinc. If the zinc be put in at first it will evaporate or "burn out" before the copper melts. If heated too hot after melting the zinc will evaporate, passing into the air and coating surrounding objects with white, feathery flakes. If kept melted long a little more zinc should be added if the solder is to be used on brass, but for iron considerable zinc may burn out before it deteriorates. It is cast in ingots, heated red and ham-

mered while hot. If too hot it will cake, but if at just the right temperature it will granulate into fine, lustrous particles, not loosing their metallic yellow color.

It is used on brass, copper, iron or steel, with a blowpipe or a forge.

Silver solder is composed of silver, copper and zinc. The silver imparts to the solder strength, malleability and protection from oxidizing. The copper tenacity and malleability. The zinc lends fusibility.

The object in making a silver solder, is to so alloy a metal that it may be strong, malleable, not liable to oxidize, and fusible. The difficulties to be encountered are that an easily fusible metal is not strong and tenacious, and when alloyed with a metal of hard fusibility, produces a brittle alloy. The brittleness is not relieved by reducing the quantity of the fusible metal, since an alloy composed of a large quantity of a metal that is hard to fuse and a small quantity of one easily fused is more brittle than if the metals are in reverse proportions.

An alloy of silver in large proportion and zinc would be easily fused and hard to oxidize, but brittle. We therefore retain enough of the silver to prevent oxidation, reduce the zinc as much as possible and retain the property of easy fusion, and add copper to get strength and tenacity.

The proportions for a good hard solder are about, Silver 18, Copper 4, Zinc 1, by weight. They may be alloyed in a crucible, and if done so, should have the silver and copper melted together first with just heat enough to make them unite, under a flux of borax. Then add the zinc and pour into an ingot mould immediately. Or, coin silver may be melted first, and one-third its weight of

spring brass, cut up in fine pieces, added. Pour as soon as it presents a clean smooth surface. Put in borax as before for a flux. It should be cast thin and rolled without annealing.

If you want a little for your own use, and do not care to keep it on hand a long time, weigh out 3 or 4 pennyweights of coin silver and one half as much of clean spring brass. I say spring brass because that is an alloy of copper 2 parts, zinc 1 part, by weight. It is a light yellow color. Red brass should be avoided. Cut the brass in thin shreds. In a piece of charcoal cut a hollow near one side about the size of a teaspoon bowl. Put the silver in and add a little borax. Melt the silver with the reducing flame of the blowpipe. (Chapter IV.) Add the brass and keep a gentle flame on until the brass is absorbed and it presents a clean smooth globule *and no longer.* Lay down your blowpipe and pick up a flat piece of iron not less than a sixteenth of an inch thick. Place the iron on the edge of the charcoal and rock it over on the melted globule so as to flatten and cool it at the same time. Put it through the rolls or otherwise make a sheet of it, but do not anneal it. Heating the surface oxidizes the copper, evaporates the zinc and makes it harder to flow. For convenience the same strip may be rolled to different thicknesses to suit the work on which it is to be used.

If for any reason it is to be remelted, a small piece of zinc should be added while in a state of fusion to take the place of that evaporated. Too much zinc causes it to lose strength and to turn dark when exposed to the air.

Some add a three-fourths part of metallic arsenic to make the solder more white and fusible. It also makes it

more brittle and the fumes from the arsenic must be avoided since they are deleterious. If used it should be added at the last moment.

Articles of gold are sometimes soldered with gold of a lower grade. For 22 carat gold, add to a pennyweight of the gold 2 grains of silver and 1 grain of copper, and the same proportion of silver and copper for gold of 18, 16 or 14 carats, with which to solder them. For the manufacture of articles that are to be exposed for any length of time to the action of acids, as in dental work, they should be used. For articles of ornament and for the repair of jewelry, spring brass may be used instead of the silver and copper, making a solder of good color and more easily fused. Some use with coin gold, the same proportion of brass as for silver solder. The same precaution should be used in making as for silver solder, to add the brass, which contains the more fusible metal, zinc, last, and to cool as soon as alloyed, to prevent the volatilization of the zinc.

Gold of a fineness of 12 carats or less may be soldered with 10 or 12 carat gold to which about 2 grains of zinc to the pennyweight has been added, but in no case should a gold solder be made that is less than 8 carats fine. The gold is wasted by not being sufficient in quantity to protect the alloy from oxidizing. It is better for such work to use silver solder.

Gold solder for general work may be made of Gold 18, Silver 4, Copper 5, Zinc 2 parts, by weight, or, to 1 dwt. 18 carat gold add 5 grs. spring brass. This will be 15 carat gold. Tin is sometimes used instead of zinc, but it makes a more brittle alloy owing to its easier fusibility.

The gold solders are made on charcoal, pressed and rolled as described for silver.

CHAPTER III.

OXIDATION.

While the oxygen of the air is of the greatest assistance in producing the heat that the workman employs, it also becomes his greatest enemy in the property it has of uniting with the metals of which his work is composed. In welding, brazing, hard soldering or soft soldering, only chemically clean metallic surfaces will unite. The pure metals must come in contact in order to establish permanent affinity.

Nearly all the metals and alloys in common use oxidize. The oxidized metal is the red rust or the black scale on iron or steel; the white oxide of zinc; the red oxide of lead; the yellow oxide, or litharge, and the white oxide, or white lead; the black oxide of copper; the oxide of tin, called putty powder.

Gold derives its superior value from its properties of resisting the oxidizing power of the air and water, its malleability and its scarcity. Silver derives its value from the same properties, but possessing them in a less degree, while it is more abundant, is cheaper in market value.

In the working of metals the workman resorts to other substances that possess the power of resisting the action

of the oxygen and of uniting with the oxides of the metals, if formed. Different substances are used, adapted to protect the metals at the degree of heat required for the process used. In welding, borax is used, because at a red heat it melts and flows over the surface of the iron, protecting it from the hot air of the forge and uniting with the oxide or scale if formed. In brazing and hard soldering the same substance is used for the same purpose. When the temperature is not raised to a sufficient extent to melt borax, sal ammoniac, muriate of zinc, resin, Venice turpentine, and even tallow and sweet oil may be used, as in soft soldering and the tinning of iron. These substances are called *fluxes*, and are used for the one purpose of protecting the metal from the oxygen of the air. The beginner must not get them confused, for while borax is the shield at a high temperature, it is not only useless but in the way at a low one, and while tallow or oil will flux at a low temperature and when used alone, they have the opposite effect at a little higher temperature or mixed with other fluxes.

Charcoal also operates to protect metals from the oxygen of hot air by itself uniting with it, or in a vicarious way. The workman who solders on charcoal can often protect one side of his work from oxidizing by causing it to fit the coal tightly. The charcoal burns around the work and consumes the oxygen before it reaches the side in contact.

Other substances called antioxidizers are used to protect the surface of metals from the action of the air where solder is not intended to flow. The blacksmith "lutes" his steel dies, or the gunsmith his engraved work, with clay. The jeweler coats his work with yellow ochre and

other substances given hereafter, for the same purpose. They act in a mechanical way by being interposed between the surface to be protected and the air.

To resist the action of the air upon articles in ordinary use the gunsmith blues or browns the surface, that is, he produces on the surface a coat of oxide to prevent farther oxidation; the brass finisher "ormolus," that is, heats until a light coat of oxide forms and then applies a light coat of shellac; the electro-metallurgist plates with gold, silver or nickel. For the same purpose sheets of iron are tinned and coated with zinc. Zinc, although freely oxidizable, takes on a coat of oxide impervious to air or moisture, thus preventing further oxidation.

Of anti-oxidizers, the most important ingredients are yellow ochre and borax. The workman may compound to suit himself. To prevent steel from scaling, yellow ochre and water forming a paste to spread on will answer the purpose. To prevent alloys of gold from changing color, pulverized borax should be added to the ochre, as also a little aqua ammonia to assist in forming a paste. A good recipe is

Borax, - - - - -	1 oz.
Aqua Ammonia, - - - -	½ oz.
Yellow Ochre, - - - -	1½ oz.

Water to make a paste.

Some add also pulverized charcoal. If kept tightly stopped it seems to improve with age.

The means of removing oxides formed in hard soldering and of restoring the color to alloys will be considered in Chap. VII.

CHAPTER IV.

STRUCTURE OF FLAME.

Since the flame of the lamp is of general use in soldering, it may be well to devote a little time to the study of its structure. The flame is produced by the combustion of gases. In the case of alcohol or oil, the liquid at the end of the wick is raised to a temperature at which it volatilizes. The gases are then heated until they combine with the oxygen of the air, in turn producing heat and volatilizing more of the liquid. The wick of the lamp or candle conveys the liquid to the point of combustion to maintain the supply. The gases as they arise from the wick come in contact with the oxygen in the air, with which they unite. As the stream of hot gases flows upward the outer portion comes in contact with the air first, and the inner portions as they pass upward are presented to the air, Fig. 4, causing the flame from a round wick to be conical in shape. Where the process of the union of the gases is going on, that is at all points of this cone of flame, *B*, Fig. 4, the elements are raised to a high degree of temperature. The highest tem-

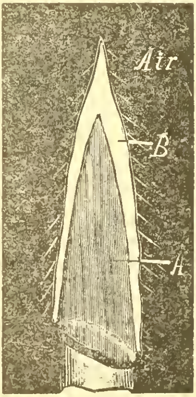


Fig. 4.

perature is at the apex of the cone where combustion, or oxidation of the gases, is proceeding from all sides. Inside of this outer cone of flame is a space comparatively cool, but filled with gases at a temperature sufficiently high to oxidize if brought in contact with the air, *A*, Fig. 4. If a wire gauze be held across the middle of the cone the flame will be cut off at that point and the flame below presents a ring of combustion. The reason that the flame is cut off by the wire gauze is that the heat is conducted away by the metal and the gases cooled thereby below the temperature at which combustion takes place. If a piece of watch spring be inserted across the lower part of the flame it will be heated to redness at two points where it crosses the outer cone of combustion, while the portion in the interior of the flame will be below that temperature. In the flame from oil lamps and candles this cone of intense heat is luminous.

If the point of the blowpipe be inserted in this cone, Fig. 5, and through the small aperture in its end, a jet of air be blown, the heated gases in the interior of the flame are supplied with

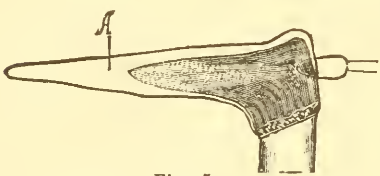


Fig. 5.

oxygen and combustion is carried on from within, increasing the combustion and consequently the heat. The stream of air elongates the flame in its direction and exposes it to a greater air surface. This flame is technically called the oxidizing flame, from the fact that it carries with it a quantity of free heated oxygen, that unites with the heated metal, carbon of the charcoal, &c. If it be

blown on a piece of bright iron or steel, as the oxygen unites with the surface exposed, it passes through the tempering colors, straw, purple, blue, and if the process be continued to a red heat, a hard black scale of oxide of iron is formed covering the surface to a depth corresponding to the duration of exposure. Pure gold and silver are but little affected by it, as they unite with oxygen only to a slight extent, but copper is very susceptible to the action of hot oxygen, losing its metallic lustre, and assuming a dull brown color. It causes alloys of which it is an ingredient to do likewise. Zinc is volatilized by the heat, and the vapor coming in contact with the hot oxygen, unites, forming fleecy white particles of oxide of zinc that float in the air or adhere to the charcoal. Tin at a little above its melting point is entirely oxidized and converted into putty powder. Lead does likewise, but the oxide is yellow and heavier, commonly called litharge.

If the point of the blowpipe be held at a little distance from the lower part of the flame and a gentle blast be blown over the flame, as in Fig. 6, the flame is diverted in the direction of the stream of air, and the flame supplied with oxygen from the outside. The inner cone of heated carbonaceous gases, *A*, Fig. 6, remain ready to unite with any oxygen with which they may come in contact. Oxidized metals in the interior of this flame are deprived of their oxygen and reduced to a metallic state. It is therefore called the *reducing* flame.

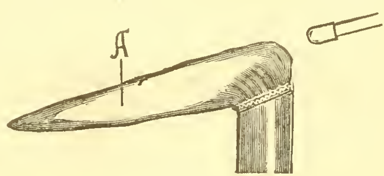


Fig 6.

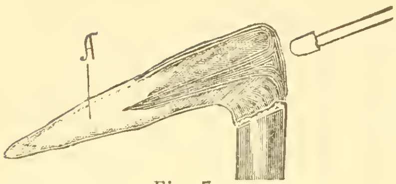


Fig. 7.

If the point of the blowpipe be held just at the edge of the cone of combustion as in Fig. 7, and a gentle blast blown, a double cone may be formed, having a point of intense heat at *A*, with neither oxidation or deoxidation.

These different flames are utilized in soldering by ap plying the intense heat of the oxidizing flame to raise the temperature of the cold article to be soldered, if it be large, before the solder is applied. Also, when it is necessary to call to his assistance the heat of the burning charcoal, it supplies the carbon of the coal with heated oxygen to assist its combustion. When the process has arrived at that stage at which the solder fuses it is necessary to protect it and and the joint into which it is expected to flow from oxidation. The blowpipe is then withdrawn, producing the reducing flame.

On coarse work the oxidizing flame may be used to save time, but on light repairing and gold alloys too much care cannot be exercised to use the reducing flame.

CHAPTER V.

HEAT.

Heat is transmitted by conduction or convection, radiation and reflection.

Heat, in solid bodies, seems to be transmitted from one particle to the next by a slow process called conduction, and in liquids by the movement of the particles to and from the source of heat.

Heat radiates or passes through the surrounding air, like light, with great rapidity. It is in this state governed by laws similar to light, being capable of reflection.

It may be produced by chemical action and transmitted by any of the foregoing methods. It may be developed within a body by causing it to obstruct a current of electricity or motion.

For the work of which we are treating the main source of heat is by the combustion of coal, gas or liquids—the union of the oxygen of the air with carbon or hydrocarbons. The work may be immersed in the burning coal, receiving heat from all sides, as in soldering and brazing; the flame from liquids or gas may be driven onto it as in hard soldering, or it may be conducted to the work as in soft soldering.

By whatever means the heat be imparted to a body, as soon as it is introduced it strives to equalize itself through-

out the body and to escape by every means of transmission. As the heat seeks to escape from the workman by every method, so must the skilled workman employ every method to lead the heat to the point desired and make it culminate in accomplishing his designs.

The escape of heat by conduction varies in different bodies. If you take an iron spoon and a silver one and hold the bowls of both in hot water, you will feel the heat in the silver one some time before you do in the one made of iron. From this you may learn that you can heat a portion of a bar of iron without losing much heat by conduction if the process be carried on briskly, but an attempt to heat a spot on a similar silver bar would be attended with considerable loss of heat by conduction.

The relative conducting power of metals is given in Fowne's Chemistry as follows.

Silver, - -	1000	Steel, - - -	116
Copper, - - -	736	Lead, - - -	85
Gold, - - -	532	Platinum, - -	84
Brass, - - -	236	German Silver, -	63
Tin, - - -	145	Bismuth - -	18
Iron, - - -	119	Zinc (Mech. Dict.) -	363

Another principle to be taken into consideration in this connection is the amount of heat required to raise the temperature of different metals. Metals differ in their capacity for heat. Iron requires more heat to raise it a certain number of degrees of temperature than silver, so that although there is not so much loss of heat at any given point, by conduction, it is necessary to impart more heat to raise the temperature of the whole iron bar an equal number of degrees than the one of silver. This capacity

for heat of any substance is called its *specific* heat. A celebrated French experimenter, Regnault, gives the following numbers to express the relative specific heat of the metals as compared with water:

Aluminum, -	0.2143	Mercury, - -	0.0333
Antimony, - -	0.0508	Nickel, - -	0.1086
Bismuth, - -	0.0308	Platinum, -	0.0329
Copper, - -	0.0952	Silver, - -	0.0570
Gold, - -	0.0324	Tin, - -	0.0562
Iron, - - -	0.1138	Water, - -	1.0080
Lead, - -	0.0314	Zinc, - -	0.0955

It will be seen, for an example, by comparing the tables, that copper has a high conducting power and also a high capacity for heat, thereby being hard to heat, while platinum is a poor conductor and also has a low specific, rendering it easy to heat.

As soon as a body becomes heated more than the surrounding matter it loses heat by radiation. The heat projects in right lines into space from all points of its surface. The capacity of any body to radiate and to absorb heat is equal. Radiation is varied by the condition of the surface of a body. Dark or rough surfaces lose more heat by radiation and absorb more than light or polished sur faces. Blackened tin having a radiating power of 100, clean tin will radiate but 12, and if the surface be roughened by scraping, 16 will indicate its power of radiation. Radiant heat, or in other words heat that has been radiated from an over heated body, is subject to laws of reflection similar to light, in which case the heat rays are thrown off from the body without entering. Hence if a body reflects the heat it does not absorb it, and vice versa.

Having considered the methods by which heat escapes from a body, we may now review the ways the workman has of applying the heat and preventing its escape. In common use we have the flame of the lamp or of gas; the heat from the burning coal on the hearth or in the forge; the heat from conduction from hot tongs, the copper, and sometimes by pouring melted metal over a body. To the flame of gas or the lamp which raises the temperature, as explained in another chapter, by contact with gases in a state of combustion, we often add the heat radiated and reflected from burning charcoal, and cover parts that are not exposed to the flame with some poor conductor of heat, such as clay or plaster of Paris, to prevent the radiation of the heat absorbed by conduction. In the forge the temperature is raised by contact with burning solids, conducting, radiating and reflecting the heat. In some instances where heat and pressure combined are necessary, heated tongs are applied, thus heating by conduction and at the same time retaining the parts in position during their expansion. When the work is too large for other methods it is sometimes imbedded in sand or other poor conductor, leaving the portion to be heated exposed so that melted metal may be kept running over it until the part is raised to the desired temperature by conduction from the melted metal.

CHAPTER VI.

THE PROCESS.

We will suppose the reader to be provided with the tools and material described for hard soldering, but in the art to be a beginner, and we will suppose him to be trying to learn with the mouth blowpipe, the alcohol lamp and charcoal, since when these are learned the other methods are easy.

Select a place for the work table away from sunlight or other strong or bright light, in order that the flame may be more readily seen, and its character distinguished.

Place the lamp directly in front, the pieces of charcoal to the left. Next the lamp on the right put the tweezers and some solder cut up in little squares proportioned to the size of the joint to be made, then the slate and borax, the wash bottle and the blowpipe.

Take for an experiment a piece of brass wire an inch long which it may be desired to unite to a narrow strip of sheet brass. With a flat file, file the wire half away, leaving it flat perhaps a quarter of an inch from the end to a shoulder, leaving the filed surface clean, bright and dry. File or polish bright the end of the strip of sheet metal where the wire is to lay. Do not touch these clean surfaces with the sweaty hands. Place the piece of wire

on the sheet metal as you want it when solid and wrap a piece of the iron binding wire twice around near the end of the brass wire, lap the ends over the round wire and twist tight. Make a similar wrap of wire near the end of the sheet metal. Blow a drop of water from the wash-bottle on the slate and rub the borax in the water until a paste is formed. Apply a coat of this paste all around the edges where the two pieces come in contact. Lay the work on the charcoal so that the joint will come near its right edge. Take the cover off the lamp wick and light the lamp. Grasp the charcoal with the left hand, taking such a hold that the flame will not reach the thumb or fingers and having the palm of the hand in a vertical position so that the little sparks of ignited charcoal that may become dislodged will not fall into the palm of the hand.

Place the blowpipe to the mouth with the nozzle directed to the left and just outside the lower part of the flame. Fill the cheeks with air from the lungs and blow sufficiently hard and steady to give a permanent lateral direction to the flame. Bring the work into the flame first one side of the joint then the other. The heat will be conducted to the work and cause the borax to expand, but if the heat be continued it will settle down again, having been deprived of the water of crystalization by the heat. Now stop the blast, care being taken not to inhale through the blowpipe.

With the tweezers pick up a piece of the solder, and after touching it to the borax paste to moisten it and cause it to adhere to the work, place it beside the wire between the wraps of binding wire.

Apply the flame as before, heating first one side of the joint, then the other, but not on the joint until it becomes nearly red hot, then apply the flame to the joint until it becomes red hot and the solder melts and flows all through the joint. As soon as the solder flows quickly remove the blowpipe. It is easy to tell when the solder flows for while it is melted it glistens with radiated light.

Blow a stream of water from the wash-bottle on the charcoal to extinquish the fire and cool off the work.

It will be necessary for the beginner to practice with the blowpipe in order to blow a continuous stream of air through the blowpipe nozzle while he breathes through his nostrils. To one not accustomed to the blowpipe it seems a paradox, but is, nevertheless, easily acquired by any one the anatomy of whose throat is perfect.

If you close your mouth and fill your cheeks with air until they are distended you will find that you can close the passage between the mouth and throat so that while you breathe through the nose the cheeks remain full. Then if a blowpipe be inserted in the mouth and this passage closed the blowpipe will not permit the air to escape from the cheeks so rapidly but that the lungs may be filled by inhaling through the nose while the muscles of the cheeks are forcing the air out of the blowpipe. When the lungs are replenished the passage is opened and the cheeks refilled.

Begin by breathing naturally with the cheeks full, then put the blowpipe in the mouth and practice until you can breathe right along naturally, replenishing the cheeks whenever necessary. After you have become accustomed to blowing it will not be necessary to replenish the cheeks

every breath or to have the cheeks much distended, and you will be able to perform the whole operation without it distracting your attention from the other parts of the process.

If the beginner has trouble in acquiring dexterity he may take a rim fire cartridge shell and make a hole in the end smaller than the hole in the blowpipe nozzle, at first, so as not to empty the cheeks too fast. Put it between the lips in the place of the blowpipe and practice blowing through it. As skill is acquired enlarge the aperture until it becomes as large or larger than the one in the blowpipe. It may be carried in the pocket to practice with at any moment of leisure.

If the beginner is now ready for another experimental lesson he may make a ferrule. Procure a piece of sheet iron, brass or silver, and place on the charcoal. Hold the blowpipe point just outside of the lower part of the flame and blowing the flame upon the sheet metal, heat it red hot. If of iron allow it to cool gradually, but if of brass or silver blow a jet from the wash bottle on it until it is cool. It will then be annealed, and if you make any particular measure you will not be annoyed when it is done by finding that it has expanded in hard soldering and does not fit.

Cut out a strip as wide as your ferrule is to be and as long as its circumference. Form into shape, keeping the edges to be united clean. If the metal is thick and the joint well fitted, it may be soldered without binding; but if the metal be light or the ferrule long, put a couple wraps of binding wire near each end to hold the edges together. If of brass, silver or gold, put a strip of flat sheet brass lengthwise along the back of the ferrule opposite the joint

and wrap the binding wire around both. Brass, silver or gold, in heating, expand more than the iron binding wire and are more pliable when hot. If the binding wire be wrapped directly around them, by not expanding so much it sinks into the hot brass, silver or gold, and makes grooves around the ferrule, sometimes causing much annoyance to restore to shape and polish out.

When you have it wrapped and the edges fitted closely together, take a file and run along inside the ferrule lengthwise of the joint, to remove the burr and scale and brighten the metal near the joint, to facilitate the flow of the solder. If of iron or brass spread on plenty of borax paste inside and out; but if of silver or gold enough can be spread on with a small pencil brush, as those metals do not oxidize materially, and do not require *much* fluxing, but it should be evenly applied and cover every exposure of the joint.

Make a little hollow in the charcoal and lay the ferrule in, joint down. Put a small piece of coal near the end farthest from the flame. Hold the charcoal so that you can blow through the ferrule if you desire, and, applying the blowpipe flame, heat all over evenly until the borax settles. With the tweezers take a piece of solder, as before, and touching it in the borax paste, lay it on the joint inside of the ferrule at a little distance from one end, and another piece near the other end; if the ferrule be long put one or more pieces in the middle.

Now apply the flame to the outside of the ferrule on top until it becomes nearly red, then direct it inside, as far in as you can conveniently, and downward along the joint until the solder flows.

If of silver or gold see that the blue flame does not impinge on the edge of the metal long in the same place, as it may melt down, and if you see the metal at any time begin to crinkle or shrivel, throw off the flame as soon as possible. If the solder should not flow up to the end do not direct too much heat there, as those corners are easily melted away. It is better to put on fresh borax, a new piece of solder, and try it again.

The solder should not be as thick as the gold or silver sheet, but the brass or iron will stand for almost any thickness of solder to melt.

Some workmen put the joint uppermost on the coal and apply the solder on the outside.

We will next take a job of repairing, for instance a silver teaspoon that has been broken across the middle of the shank. The joint may be made by squaring the broken ends and putting them flat together, depending on pinning the work to the charcoal to hold it in place while under heat. It may be made by sawing into each piece and inserting into the kerfs a piece of silver, as in Fig. 8.

8

9

10

It may be made by holding each end on an anvil and drawing to a bevel edge with the pane end of a hammer, making a bevel perhaps one fourth of an inch long on each piece, then file smooth and bright and laying the two beveled ends together, as in Fig. 9, wrap with binding wire. If the spoon is to be united in any of these ways it should be fastened to the charcoal with pins made by

cutting off pieces iron wire, about No. 20 in size. If it is not convenient to pin to the charcoal the latter joint may be made with a notch in it to prevent slipping apart, as shown by Fig. 10, when the binding wire will retain the pieces in position in every direction.

A piece of charcoal should be selected as long as the spoon, on which it may lie so that the joint and the ends will rest on the coal. Pin it to the coal if necessary, and apply the borax paste. Put a small piece of charcoal on top of the larger piece, on the side of the spoon and opposite where the flame will strike when blowing on the joint. If this piece has a beveled side, so as to project over the spoon at the joint, so much better. Place a piece of coal on the spoon bowl.

Direct the flame on the coal around the spoon, to ignite the coal and to heat the borax. When the borax has settled, put on a piece of solder, this time a thick one, so that it may not melt and burn before the metal of the spoon is hot enough for it to flow in the joint. It should be about half as thick as the metal at the joint. Apply the flame first one side of the joint then on the other, until these parts are nearly red hot. By doing so the heat will be conducted into the metal at the joint, and heat it gradually, without melting the solder, the object being to apply the heat in such a manner as to heat the metal at the joint without permanently melting the solder. By having these parts hot when the flame is applied to the joint to melt and flow the solder, the heat will not be conducted away, but will suddenly raise the temperature to the required degree without oxidizing the solder or volatilizing any of its component parts, and also economizing

the heat of the flame, the theory of which has been explained in foregoing chapters.

When the parts on each side of the joint show nearly a red heat, see that the point of the blowpipe is outside of the flame, and direct a gentle blast on the joint until it becomes red, the solder fuses and a bright glistening line along the joint tells that the solder has run through.

It is common for the beginner to blow too hard, and to hold the work too close to the lamp, with the hope of thereby increasing the heat. The blast when the solder is to be fused should be moderate, and the work at the blue apex of the inner cone of the flame, a point that can readily be seen by removing the work or by slackening and then gradually increasing the force of the blast.

If from poor borax, an unclean joint, or an improper application of the heat, the first piece of solder does not flow as it should, another piece with a little fresh borax may be added, and the work again heated. Sometimes the workman may be annoyed by the solder forming a globule, dancing around and refusing to flow into the joint. In such a case, if the metal below is hot enough, it will sometimes flow if the blast be suddenly checked or withdrawn. If it continues long, so as to volatilize the more fusible parts of the solder, remove the globules and as much of the old borax as is practicable, and apply fresh borax and solder, and take a new heat. When the work is required to possess the utmost strength, and will stand the heat, it may be kept heated after the solder has run, in order that it may alloy deeper into the metal of the work, and make the metal at the joint more homogeneous.

If the spoon had cracked down the bowl and it were re-

quired to repair it, the edges should be brought together at the top, and a hole punched in each near the corner, through which to bind with a piece of silver wire large enough to fill the holes, or, rivet a piece of silver on. The surplus metal can be dressed off after soldering. It is necessary in the case of cracked pieces of concave form to provide against the unequal expansion from heat, as it tends to open the crack. A secure method of retaining the parts having been provided for, proceed as before. Place a small piece of charcoal in the spoon bowl, to counteract radiation of heat.

CHAPTER VII.

THE PROCESS—Continued.

We will suppose that by this time our apprentice has become familiar with the blowpipe, flame, and materials on his table, and desires to replace a broken joint on a silver watch-case. He will find the ends of the outer joints plugged with little tapering pieces of silver, that he may remove by cutting into slightly with an engraver's chisel, and pressing them out. The joint pin may then be driven out by inserting a small punch in the hole and pushing from left to right. The old pieces of joint should be removed entirely, and the hollow seat dressed smooth and bright with a round file. From a piece of hollow wire of the size of the joint cut a piece a little long, and fit to the exact length between the joints. Examine it to find on

which side it is closed, dress it bright on that side and mark it so that the joint in the wire may come on the case and be soldered up when it is united to the case. If it is a light case, and the hole in the joint wire small, there is danger that the solder may flow into the hole and fill it up. To save this prospect of future trouble, the careful workman dresses a piece of pencil black lead, to fit the hole in the wire. The properties of the black lead or plumbago, that make it useful for this purpose, are that the solder will not unite with it, that it is not altered by heat, and that it may be crumbled to powder to remove it, if necessary.

Having marked the exact position that you desire the joint to occupy, if you intend to retain it in position by passing iron binding wire around the whole cap, it will be well to fit a heavy piece of brass wire across inside the cap from flange to flange, or the silver of the case in expanding more than the iron binding wire, will be contracted out of its natural shape unless supported. Heavy wire should not be used to bind such a job. When light wire is used it should only be wrapped twice around, so that if it be seen to be doing damage it may be easily burned asunder by the point of the flame. The wire is not usually needed after the solder is applied.

Apply the borax and put it on the charcoal. Your solder this time should be thinner than the material of the joint wire, and cut into small pieces so that it will not be necessary to use more than enough to answer the purpose, since the surplus may flow into places where it will be disagreeable to remove. Place some small pieces of charcoal inside the cap, and blow the flame over them, to par-

tially ignite them. Heat enough to calcine the borax. Put a piece of solder either alongside or near the end of the joint. Heat every part of the cap but the joint, and ignite the pieces of charcoal within to prevent the escape of heat by radiation, and thereby prevent the heat from being conducted away when the critical moment arrives. The carbon of the ignited charcoal will also unite with the oxygen of the air, and tend to prevent oxidation of the work. When it is all well heated, apply the heat to the joint and the metal adjacent, carefully watching that no one point shows too luminous, or otherwise indicates that it is receiving too much heat. The work should be kept slowly moving under the flame, so that the blue cone will not come in contact with a thin edge of metal at the same place any length of time, or you may see the edge shrivel and melt before you are aware of the intense heat.

Watch intently for the bright glistening line along the joint that announces that the work is done, and quickly remove the flame to save farther danger.

With the wash bottle blow a stream of water on the coal around the work until the main piece is quenched, but do not direct the stream onto one side of the cap, or in any way cause it to cool from a high degree of heat suddenly, or it will warp. If the coal be quenched around the cap, and the pieces of coal inside removed and quenched, it will now be cool enough to remove from the coal and take off the iron binding wire, when, while slightly warm it may be immersed in the silversmith's pickling solution described in the next chapter. If immersed a little warm, the black oxide is sooner removed.

Had the cap been of gold, it would have been neces-

sary to cover the surface with an anti-oxidizing paste, to prevent loss of color by the copper of the alloy oxidizing in the presence of the hot oxygen.

The caution in regard to iron binding wire, and sudden cooling springing the work, applies to dental plates, or any work having an accurate form to preserve.

In brazing or hard soldering large pieces, when it is necessary to use a hearth or forge, the pieces are bound together with heavy annealed iron wire, large enough not to burn off in the fire. Since the heat cannot be managed so well as with the flame and blowpipe, it is sometimes necessary to lute, or cover with clay, the lighter or more exposed portion of the work, to protect it from the heat. The same care is used to have the joint clean and bright, and the same rules observed in regard to the borax and solder, as in soldering with the flame. Charcoal is best, but if not at hand, and bituminous coal is to be used, it should have the sulphurous gases driven from it by burning to a coke before putting the work in the fire.

It is sometimes necessary to unite long thin strips of metal that cannot be fastened on anything to hold the ends in position, since the fastenings would have to be applied at a distance from the ends to be united, and when the heat would be applied the expansion would cause them to buckle out of shape. To unite such articles, as for instance a band saw, prepare the end for a lap joint. Lap the ends more than the width of the saw. Cut a notch, larger than the lap, in a block, and fasten the pieces so that the edges of the back may be in line, and the laps

in position over the notch. Fasten to the block by screws or clamps. Cut a piece of silver solder, rolled thin, as large as the lap. See that the solder and the faces to be united are clean and bright, and insert the the solder between the lapped surfaces. Apply the borax paste all around the edges. Heat the jaws of a pair of tight shutting blacksmith's tongs red hot, and shut them onto the joint, inclosing joint, solder, and all. If the jaws are so light as not to close firmly, screw a clamp onto them. Cool with a stream of water. The heat from the jaws of the tongs is sufficient by conduction to flow the solder, and the pressure retains the parts in position and prevents buckling.

The solder may sometimes in blowpipe soldering be applied to advantage by placing a thin strip in the joint.

CHAPTER VIII.

TECHNICAL NOTES.

It may be of advantage to the student in the art of hard soldering to introduce a chapter containing notes, partly in review, to impress the important points more firmly in the mind; and partly novel, being such ideas as have been derived from practice and experiment, and which may sometimes save, even to an experienced hand, many times the price of a little book.

Sometimes parts to be united have edges or corners so thin as to be almost certain to be "eat away." This eating away or shrinking is caused partly by the heat coming in contact with a large area of metal in proportion to the bulk. Conduction does not equalize the heat fast enough to carry it away from the thin place, thus it becomes heated more than the adjacent thicker metal, and melts, or comes near the melting point, before the solder flows When the solder flows it alloys with the thin hot edge or corner, and causes it, too, to flow toward the thicker or cooler metal. It may often be prevented by inserting in the joint a thin piece of sheet metal, of the same material as the body of the work, and a little larger, so as to extend beyond the thin edge, as in Fig. 11. The solder must be flowed on both sides of it. It conducts the heat away from the thin edges and attracts the flowing solder outward to make a perfect, full joint. The surplus metal is afterward dressed off. Such a piece is often useful also in gold rings that have been worn to thin edges, or have been resoldered so many times that the solder has alloyed with the body of the metal and causes it to melt easily. It is a good plan to insert such a piece in cutting down and hard soldering rings filled with hard solder, in which case it is not necessary to use any hard solder on the outside, since if the piece of sheet metal be properly cleaned the filling will flow, but it is safer to use a little, if for nothing else than to tell when to stop the blast.

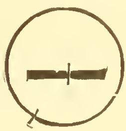


Fig. 11.

The silversmith's "pickle" is made by diluting nitric acid with ten times its bulk of water, putting it in an open vessel like a pickle dish and adding as much sulphuric acid, by measure, as was used of nitric acid. The acids should not be mixed in a tight vessel. If the pickle stands exposed to the air it will evaporate, but is restored again by adding water. Iron should never be allowed to get in it. Articles should never be taken out of it with steel tweezers; the binding wire should be removed from all articles before they are put in. Whenever by any means iron gets in the solution it is dissolved by the acids and held in solution. The pickle also holds copper in solution. These are ready to be deposited whenever the acid comes in contact with any metal for which it has a greater affinity, therefore it deposits a coat of copper when iron is presented, and a coat of iron when silver is presented, coloring the work instead of cleaning it.

Restoring color to gold alloys is a subject on which the author has spent a good deal of time in investigation and experiment. If an alloy of gold, containing gold, silver and copper, be heated in contact with oxygen to a red heat, without any anti-oxidizer to protect the surface, it becomes coated with a brown scale. It is only surface deep, and may be polished off in many cases. We have seen that gold does not oxidize to any appreciable extent; that silver has not much affinity for oxygen, but that copper is easily oxidized. If we now dip it in the silversmith's pickle the sulphuric acid will remove this oxide of copper, and leave a surface composed of gold and silver,

consequently it has turned pale, or lost its color. The problem then is when the copper has oxidized, to remove the copper oxide and as much silver as the alloy contains in proportion to the copper that has been lost by oxidation. The only chemical reagent known that has an affini ty for silver and not for the other metals is chromic acid. Sulphuric acid removes the copper readily, but not the silver. Chromic acid is not commonly kept for sale, but is, fortunately, easily made. Take a bottle and fill half full of bichromate of potash. Then fill the bottle nearly full of sulphuric acid. The sulphuric acid has a greater affinity for the potash than the chromic acid. It unites with the potash and liberates the chromic acid. It works best warm. If the article be dipped in it when the solution is warm and allowed to remain a short time the chromic acid unites with the silver of the surface, and removing it, restores the alloy to its original color. It may be restored after having been dipped in the silversmith's pickle or without. The solution may be used cold if the article be plunged in hot, but it is not so easily regulated, as the acid operates quickly under such circumstances. It must not be allowed to remain in too long, or it will assume a dirty brown color. The chromic acid should be kept in a vessel tightly closed, as it evaporates if exposed to the air. If water is added to chromic acid it does not dilute it as it does other acids, but forms a new compound. I have found that this compound, after it has stood a few days, works as well as the clear acid, if too much water is not added.

Chromic acid is one of the best tests for silver, since if a drop of it be put on silver it changes its color from its

natural crimson red to a dark maroon, while on any other white metal it remains a clear transparent crimson.

Articles that have had chromic acid on them should be washed with water and brushed with chalk.

Pieces are sometimes united by a process called "sweating." The process is similar to that of hard soldering, but no solder is used. The joint is made as for hard solder, cleaned, borax applied, and heated beyond the point at which hard solder would flow. Just before the metal melts and assumes a globular form, the surface has the appearance of sweating and the particles move sufficiently to unite. At this point the heat is removed. This process is useful in repairing silver caustic holders, where the chemical action of the nitrate of silver disintegrates hard solder joints.

Steel springs may, if freshly broken and the broken surfaces are bright and clean, be repaired by soldering with good 18 carat gold. As soon as the spring is soldered, while it is yet red hot, plunge it into water or sperm oil, thus hardening it with the same heat with which it is soldered. Then proceed to temper. The tempering is accomplished if the springs are small by putting them into an iron spoon bowl and covering with sperm or lard oil, then heating the metal until the oil burns off. Larger springs may be covered with a coil of iron wire dipped in oil and the oil burned off. If the oil is burned off two or three times the springs are tougher.

When the binding wire runs across an open place in the work it is liable to burn off. It may be prevented to a certain extent by doubling and twisting the wire. The doubled and twisted wire is better for most purposes than heavy wire. It is strong, pliable, and more elastic than the larger solid wire, and is not so liable to shrink into the work.

Light pieces are often held in position on larger ones by a piece of watch spring. Heat it red hot to draw the temper, bend to a right angle and stick one end down into the charcoal. The other end projects over the work and presses down on the piece to be held.

When two ends of similar size and form are to be united, a hole may be drilled in each and a pin inserted. The pin must be clean so that the solder will flow through the hole. Drill the holes without oil.

When a long joint is to be made in very thin sheet metal the edges may be cut into at equal distances and depths, then one turned up and the next down along each edge, when they may be put together, as in Fig. 12. Retain with binding wire or an occasional rivet. After soldering dress off the surplus.

Fig. 12.

To put little studs or lugs on wire or other work, when it is difficult to retain the little pieces in place, use a long piece, as in Fig. 13, and cut off after soldering.

Fig. 13.

When two flat or square pieces of similar size and shape are to be united longitudily, the joint is easily formed by bending the pieces, as in Fig. 14, and dressing off the corners after soldering. It is frequently done in making rings smaller, repairing spec tacle bows, &c.

Fig. 14.

It is often necessary to call the attention of the beginner a second time to the fact that the body of the metal on which solder is expected to flow must be hotter than the melting point of the solder, and that it is injurious to melt the solder until the work is heated. The desire to accomplish the object of flowing the solder leads many intelligent but inexperienced workmen to go, as they suppose, directly at it by applying the heat to the solder, which fuses, assumes a globular shape, and rolls around on the borax and cooler metal beneath, but persistently, as if with a desire to annoy the workman, refuses to flow. There may be other causes, as an unclean surface, poor borax, a solder that fuses at too low a temperature, but it usually arises from a lack of heat in the right place at the right time. The work should, if possible, be a little hotter than the solder, when an attraction will be established that will draw the solder into the joint. Even when the metal beneath announces by its glow that it is above the required temperature, if the little globule of molten solder be still hotter, it will seem to be in a state of internal ebullition, and like a drop of water on heated iron, seem to be held away by its own vapor. Under such circumstances if the flame be removed for an instant, allowing it

to radiate a little heat, it suddenly drops into the joint.

Too much care in applying the flame cannot be exercised to bring the two pieces to be united to the required temperature at the same time. If the workman is careless in this respect he will be annoyed by having the solder flow on one piece, and if that state of affairs be long continued the solder alloys, and perhaps eats away a portion of the work. If of gold, although the joint may be made with a new heat and a fresh piece of solder, when it comes to be polished up it may show a spot of a different color. Heat the piece first that requires the most heat to bring it to the required temperature. If bulky, then a greater mass is to be heated, if large and thin its radiating surface is greater. The loss of heat by radiation may often be prevented by placing small pieces of charcoal on or near the work. They also seem to prevent oxidation by uniting with the oxygen of the air when they become hot. Large plates are often advantageously coated with a layer of plaster of Paris to prevent radiation. Being a poor conductor it serves to prevent the heat from escaping, and in brazing may be used to prevent exposed parts from becoming too hot. It should not be applied very near the joint since it, also, will prevent the flame from heating the metal.

It is well to use as hard a solder as the nature of the work will permit. The harder flowing solders are not only usually stronger and less liable to oxidize, but the work is more easily repaired in case of accident. It is of little use to make a solder that will melt at a less temperature than the fusing point of borax, since if it flows at

all it must be applied while the temperature is above that point.

In heating large pieces over a forge, beware of sulphur, lead or zinc. If soft coal is used, fresh coal should not be put on the fire while the process of brazing is going on. Lead or zinc sometimes get in the fire, and being evaporated and oxidized, deposit their oxides on the cooler metal of the article to be soldered. Brass, or pieces of spelter burning in the fire produce vapors of zinc, often sufficient to cause a failure of a job of brazing or welding, by being deposited on the article to be brazed or welded.

When it is desired to flow solder in a crack for the purpose of filling it up, the solder should, if practicable, be flowed on both sides, if it extends through. Solder may sometimes be advantageously placed on the opposite side of a plate from the one to which the heat is applied.

Small pieces of solder may be more easily picked up with the tweezers, if laid on something soft, like a piece of buck or chamois skin, or better yet, a little piece of printers' roller composition. The points of the tweezers pass below the edges of the little pieces and get a firmer hold. Rubber is not good, since it contains sulphur.

When through soldering, extinguish the charcoal thoroughly. Disastrous fires sometimes result from forgotten pieces of burning charcoal.

To prevent oxidation in holes in the work, that in gold may destroy the color, or may damage screw threads, it is of advantage to tamp them full of charcoal dust.

Beware of throwing the sharp pointed flame on thin edges.

Articles to be repaired sometimes have stones set in them in such a manner that it is inconvenient to remove them. The workman should remember that these brittle substances expand with heat; that if any portion is suddenly raised to a higher temperature than the rest, that portion expands and breaks from the cooler portion, either by cracking or flaking off. The heat then must be applied gradually, and in such a manner that the stone will be heated evenly and slowly. To assist in preserving an even temperature, all grease or dirt must be removed, and thin slices of raw apple or potato bound on the exposed portion of the stone. It keeps the flame off, and by the moisture contained equalizes the temperature.

Diamonds should be *removed*. When heated very hot they fuse and unite with the oxygen of the air, forming carbonic acid gas, which is too common to be considered valuable.

All stones composed of alumina resist the heat. These are the sapphire, oriental ruby, oriental topaz, oriental emerald, oriental amethyst, and adamantine spar. Those composed of quartz also resist the heat. They are rock crystal, amethyst, false topaz, prase, chrysoprase, cornelian, sard, the agates, onyx and heliotrope. Avoid heating jet, pearls and all ornaments of shell, ivory, bone or celluloid, unless you can keep them immersed in water.

In putting together thin pieces, which, when a perfect job is accomplished, will leave an inclosed space, a small hole should be made in one of the pieces. The air inside

will be much rarefied by the heat, and the solidifying of the solder while hot may from the pressure of the air, cause it to collapse. The little hole also allows the inclosed air to escape through it while being heated, and prevents the parts from being displaced by the expansion of the air.

The heat necessary in hard soldering anneals all metals in common use, except steel when suddenly cooled. Other metals are rehardened by hammering, rolling, drawing or twisting. Plates are most commonly hardened by hammering. Articles constructed partly of wire, as a pin tongue, may be hardened by twisting. The softer places yield to the torsion, and thereby become hard. Steel soldered with 18 carat gold may be heated to a low red heat, sufficient to harden if done with care. If soldered with silver solder, they may be hardened with a stream of water while yet hot after the flow of the solder. When any portion of steel work is to be hard, a stream of water from the wash-bottle applied to that part while red hot will harden it, leaving the rest soft. When steel is to be soft it should not be removed from the coal until black, but be allowed to cool gradually.

Some workmen fuse the borax and reduce it to a powder before using, to prevent it from expanding and displacing parts at the first heat.

For very delicate work, the hard solder may be filed into dust, mixed with the borax and applied all at once.

It is not worth while to spend time trying to hard sol-

der pieces of burnt iron, in which the interior of the metal is oxidized. The solder will sometimes flow on the outside where the borax deoxidizes it, but seldom will flow through the joint.

If an article has been soft soldered and it is desirable to hard solder it, the soft solder must be entirely removed by cutting or scraping it off. If when it was soldered with soft solder it was heated too much, the soft solder may have formed a new and very fusible alloy with the body of the work, in which case it is dangerous to attempt to use hard solder. When that is the case, the new alloy formed is more brittle and feels gritty when scraped. Consequently when scraping off the soft solder if the metal beneath the soft solder feels gritty, and continued scraping does not remove the gritty metal, it will be dangerous to attempt to hard solder. But if the soft solder when scraped off leaves the metal at the joint as soft as the rest, there will be little danger in hard soldering, if the soft solder be entirely removed.

In the foregoing work, the plain, old-fashioned blowpipe, lamp, &c., have been described, and the process conducted with articles easily obtainable. It is expected that the reader will adopt anything more convenient, if practicable. Excellent apparatus is now offered in the line of automatic lamps, blowers, prepared chemicals, &c., notwithstanding, I would recommend every young man to *learn* in such a way as to be independent of every unnecessary article. After having learned, he may make the work easier by any means practicable.

CHAPTER IX.

PROPERTIES OF METALS.

Table of the specific gravity of metals at 60° Fahrenheit, or 15.5° Centigrade:

Aluminum, -	2.60	Nickel, - -	8.80
Bismuth, - -	9.90	Platinum, - -	21.50
Copper, - -	8.96	Silver, - -	10.50
Gold, - - -	19.50	Tin, - - -	7.29
Iron, - - -	7.79	Zinc, - -	7.10
Lead, - . -	11.45		

The figures show the number of cubic inches of water necessary to balance one cubic inch of the respective metals.

Tenacity of metals is ascertained by observing the weights required to break wires drawn through the same orifice. They stand in the following ratio:

Iron, - - -	269	Gold, - - -	68
Copper, - - -	157	Tin, - - - -	24
Platinum, - -	124	Zinc, - - -	12
Silver, - - -	85		

The different metals become fusible, or melt, according to Prof. Daniel's pyrometer, at the following degrees of temperature:

METAL.	FAHRENHEIT.	CENTIGRADE.
Bismuth, - - - - -	497	258
Copper, - - - - - -	1996	1091
Gold, - - - - -	2016	1102
Iron, cast, - - - - -	2786	1530
Lead, - - - - -	617	325
Nickel and Iron, wrought, highest heat of forge.		
Platinum, not fusible in ordinary furnaces.		
Silver, - - - - -	1873	1023
Tin, - - - - - -	442	228
Zinc, - - - - - -	773	412

Alloys of metals vary from the mean melting point of the metals of which they are composed. They usually melt at a lower degree of temperature than the mean, and sometimes at a lower degree than either of the metals of which they are composed, as for instance, tin solder, composed of two parts tin and one of lead, melts at about 360° F. A hard solder, composed of two-thirds silver and one-third spring brass, melts easier than either the silver or the brass.

APPENDIX.

Mats to hold the work on, while being heated, are now made of charcoal cut into rectangular pieces and chemically treated to prevent burning when not in use. A valuable improvement. They are also made of asbestos for special purposes, as for holding dental plates, spectacle bows and for melting small bodies of metals. Magnesia blocks and carbon blocks are also used by jewellers.

Attach to your mouth blowpipe a steel point, projecting beyond the bend, to touch fused solder that does not go where you want it.

When it is necessary to use alcohol the article made from wood answers the purpose and is much cheaper. If of good quality the odor is not conspicuous, but some of it is objectionable on that account.

An investing material to cover portions of work that are liable to break by heat and to retain the parts in proper position, such as teeth in dental work and precious stones in jewelry, is composed of five parts of white beach sand and four parts of plaster of Paris. Mix dry and then add water to make a consistency easy to manipulate. A little asbestos fibre is sometimes added. When a thick body of the investing material is used, as around a denture, a strong wire is inserted in the middle of the investment to

retain it in position in case it cracks with the heat. As the metal, if it gets hot, expands more than the investment a piece of asbestos wicking may be laid in the place of the wire. It comes in balls like candle wicking and is used by steam fitters in packing hot joints. For special purposes a shallow cup of the required shape may be made to hold the investing material and the whole heated in an oven, or muffle furnace, to near the soldering point, the joints having been previously prepared for the flow of the solder. Heat and cool any article invested slowly in proportion to the thickness of the investment.

Hard solder does not alloy with platinum at the fusing point of the solder. Clean the platinum and sweat in a little pure gold at a white heat at the place where the solder is to flow. Then solder as if soldering to gold. Gold plate is now sold alloyed with platinum for springs and places requiring a stiff metal not liable to oxidize. Scraps of it should be kept separate from other gold as they do not readily mix when melted together.

Bicycle frames are constructed of light steel tubes, which sometimes break. The most satisfactory way to repair such fractures is to braze them. Dress off the ragged edges and the insides of the tubes, one half-inch from the ends, smooth and bright. Make a ring of light steel, or iron, and make bright on the outside. Coat over with pulverized borax mixed with water, to form a paste, and insert in the ends to splice them together. Drill holes and pin it in if necessary to keep the frame in shape. Heat on a brazier's hearth if practicable. If nothing better can be had use a blacksmith's forge. Use charcoal, or in the absence of that make coke by roasting the gas out of soft coal. When the fire burns clear cover the

joint with borax and heat until the borax melts. Turn the joint in the fire so as to heat evenly and then lay on a lump of spelter. Spelter is low brass, in small lumps, and can be obtained from any brass founder. When the tube gets to a low red heat the spelter should melt and flow into the joint. Silver solder is preferable to spelter but more expensive. Use the best borax and plenty of it. The frame may be wrapped with asbestos cloth, each side of the joint, to protect it from undue heat in a forge, but this would not be necessary on a hearth with double gas-jets. It is sometimes a good plan to wrap a brass wire (about No. 16) around the joint to conduct the melted solder where you want it to go. This can be dressed off afterwards. Where it is impracticable to insert a ring a wire may sometimes be wound around and left on to strengthen the joint. Do not heat above a red heat as you may burn the steel tube. If the solder does not flow at that temperature something is wrong. The surface may not be clean enough ; the borax may be old, or poor ; or the spelter may have the zinc burnt out of it. Put on more borax if it melts and does not adhere or flow, but if it does not melt get new spelter or hard solder

SOFT SOLDERING.

THE same natural laws that have been explained in relation to Hard Soldering also apply to the use of softer alloy.

The surfaces to be united must be clean and bright; the heated surfaces must be protected from the air by a suitable flux and must be heated beyond the melting point of the solder to be used.

The tools and appliances differ. While soft soldering is done over a jet of flame, as a gas burner or alcohol lamp, and the blowpipe occasionally used to direct the flame, the most common tool is the copper one, sometimes called a soldering iron. Soft solder has so much less tenacity that it is necessary to have large lapping surfaces to give it strength, or folded and locked joints, which are only to be held in position by the solder.

The ordinary solder is composed of lead 75 parts and tin 25 parts, by weight. A better flowing solder is made by adding more tin, but where much solder is used it is economy to use as little as practicable on account of its cost. When more tin is used the solder is called *fat*. This is used by jewelers in repairing jewelery. For repairing plated-ware, when the lean solder would cause the joint to dis-

color and look bad, it is preferable to use pure tin, which holds its color about as well as silver and sometimes saves re-plating the work on which it has been used.

Fluxes.—Rosin is the most common flux to be used on tinned-ware where it is only necessary to protect the surface from the air. It melts and flows over the surface to be soldered but does not ignite by the heat of the copper. It is pulverized and rubbed on the seam with a small stiff pencil brush. Solder does not adhere to iron readily. For that reason a flux is prepared by dissolving strips of metallic zinc in muriatic acid until no more will be taken by the acid and diluting with from 2 to 8 times as much water. A lump of sal ammoniac added protects the soldering copper from corrosion as well as assists to clean greasy surfaces. The chemical action of this flux is that the muriatic acid unites with the iron and deposits a film of zinc to which the solder more readily adhers. Iron that is covered with a scale of oxide may have the scale removed by immersing in dilute muriatic acid and small articles are tinned by taking them from this solution, when they have turned white, and dipping in melted solder, or tin.

The copper is usually an octagonal bar drawn out to a point by hammering, and a handle attached. Its shape should be adapted to the work for which it is to be used. The point is filed bright and kept clean and well tinned. To tin the point file it bright and heat it. As soon as it is hot enough to melt rosin cover the point with it and heat until it will melt solder. Put some rosin and solder on a board together and rub the point of the copper in it turning it occasionally until the solder adhers to the copper. Now when heated and drawn across a bar of solder a drop of solder will adhere to it and can be conveyed to the point pre-

viously coated with rosin, or zinc solution, when the drop of solder will leave the copper and unite with the article to be soldered. The copper must not be overheated or the coating of solder will burn off, or alloy with the copper, and it will be necessary to dress it over and re-tin. When they become worn and blunt from use they are drawn out cold with a hammer and re-tinned. Other metals may be used to convey the heat but copper has a great capacity for heat and is easy to draw into shape and easy to coat with tin.

A wet rag is kept at hand on which to wipe the copper to keep it clean when in use. When soldering much with acid, or on a greasy surface, wet this rag in a weak solution of sal ammoniac.

The coppers are usually heated in pots made for the purpose, using for fuel charcoal, or gasoline, but may be heated in a forge or stove. For simply stopping a hole, the surface having been prepared and a lump of solder laid on may be melted with a piece of iron, or other metal, not tinned.

In reparing joints where steam pressure is to be restrained dependence should not be placed on soft solder alone. Heat and pressure cause soft solder to ooze and eventually leak unless supported by some stiffer metal. If the joint cannot be brazed, or hard soldered, make a patch of hard metal having an ample area of surface for the soft solder to flow in and solder on.

In reparing jewelry the flux used is muriate of zinc. Rosin is not used because it spreads over the work and is difficult to clean off. Soft solder should not be used when hard solder can be, but in many cases it is the only way as where the parts of the article itself are put together with

soft solder or contain settings that will not stand the heat necessary for hard solder. Most parts to be repaired, such as pin joints, button backs, ear-ring loops, etc., are made for soft soldering by being provided with a large surface to attach with the solder, which not only gives strength but covers the solder. Care should be taken that the solder does not flow beyond the piece to be attached. The usual way to solder them on is to put some acid flux on the surface of the piece to be attached and holding it in or near the flame touch occasionally with a slender bar of solder until a little melts and flows over the surface. Clean the place where it is to be attached and put on the acid flux. Press the two pieces together and heat until the solder melts and unites with both pieces. Cool in water and brush with chalk to cleanse from any acid that may adhere.

Jewelry, with jet settings, may be mended with soft solder without removing the settings, if care is used in heating. It must be borne in mind, however, that the jet melts at about the same temperature as that required for ordinary soft solder, and ignites at a little higher temperature. Black glass used in imitation will stand heat but must not be mistaken for jet. Pearl settings should be removed, or protected from the heat. Shell and imitation cameos are held in their mountings by pieces of metal put on with soft solder and will not stand the heat necessary to hard solder. A small copper, or nickel bar, is sometimes better than the gas jet, or lamp flame, in directing the heat and solder to a certain point.

Brittannia and plated-ware may be repaired with soft solder although they sometimes melt at a lower temperature than the solder. This is done with a copper by putting on

a small portion of solder at a time and removing the copper to allow the work to cool thoroughly after each application.

Cake baskets and articles of plated-ware having wire boles and hinges of hard metal, usually brass plated over, sometimes get them broken off. Clean the parts to be united and tin over the hard metal portion. Then holding the parts in position apply the flame with the blowpipe to the hard metal part, at some distance from the joint, to prevent the soft metal from melting in the joints, as soon as the solder melts promptly remove the flame. Use pure tin for such places instead of solder. The heat does not remove the plating, or injure it, if cleaned without scouring. If discolored, apply a little of the pickle solution used in hard soldering, and wash off.

Alloys are made that melt in boiling water, but they do not flow so well and lack tenacity. They are seldom used in soft soldering. Two parts bismuth, one of lead and one of tin melts at about 200° Fahrenheit and is probably as good as any of these soft alloys.

Guns sometimes have their barrels put together with soft solder and the lug that holds the tip stock is often put on in the same manner. These lugs frequently break off and must be repaired by the same process. Scrape the parts bright and wet with the strong solution of muriate of zinc. Flow solder on the parts until it adheres perfectly. Then putting the lug in position wrap a piece of annealed wire around the lug and barrels and twist the ends tightly. Put a nail between the wire and the top rib of the gun to prevent the rib from loosening, if heated so as to melt the solder with which it is held to the barrels. Hold over a gas

jet, or flame, and heat the barrels under the lug, that is, the top of the barrels, until nearly hot enough to melt solder. Lay a piece of solder on each side of the lug and removing the barrels from over the flame, blow with the blowpipe, as in hard soldering, on the lug and adjacent part of the barrels until the exposed pieces of solder melt and flow in. Turn right side up and cool with water. Wash off the acid and cleanse where the fumes of the acid adhere to the work, to prevent corrosion. Look over the gun and ascertain the cause of the undue strain on the lug which broke it off. Some guns from faulty construction have a habit of breaking them off, which must be remedied before they will stay on, or the soldering may be blamed where it is as well done as possible.

SOLDERING ALLOYS.

We find in the books on the metals a good many alloys for hard soldering, most of which are obselete. Some improvements have been made however. The dentists now use a gold solder containing zinc, similar to that described in the body of this work for jewelers. It does not seem to be corroded by the acids of the mouth as was supposed. The zinc evaporates when the solder is fused, not only getting rid of a portion of the zinc but leaving a joint over which the same solder may flow again. Coin gold can be soldered with 20-carat solder having the other 1.6 carats of zinc but 18-carat gold is more often used having 3.6 carats brass containing copper 2 parts, zinc 1 part, by weight.

A good hard solder for brass is copper 3 oz., brass 2 oz., tin 5 oz., cheaper than silver but not quite so strong.

A white hard solder for silver, where the utmost strength is not required, is composed of silver 1 oz., zinc 30 grains.

Platinum may be soldered with pure silver.

Aluminum bronze is said to be soldered by using a flux of chloride of silver and a solder of—pure tin 900 parts, copper 100, bismuth 2 to 3 parts. Melt the copper first and add the tin a little at a time, then the bismuth and if convenient a little phosphorus.

INDEX.

ANTI-OXIDIZER........ 19, 20
ALLOYS, HARD SOLDER........ 14

BINDING WIRE........ 12
BLOWPIPE........ 9, 10. 30, 31, 32
BORAX........ 13
BRAZING........ 40

CAPACITY FOR HEAT........ 27
CHARCOAL........ 9
CHROMIC ACID........ 43. 44
COLOR, GOLD........ 43, 44
CONDUCTION OF HEAT........ 26

FLAME, STRUCTURE OF........ 21
FLAME, REDUCING........ 23
FLAME, OXIDIZING........ 22
FLUXES........ 19
FUSIBILITY OF METALS........ 54
FUSIBILITY OF ALLOYS........ 54

GOLD, COLOR........ 43, 44
GOLD SOLDER........ 17

HARD SOLDER ALLOYS........ 14
HARDENING METALS........ 51
HEAT........ 25
HEAT, CAPACITY FOR........ 27
HEAT, CONDUCTION OF........ 26
HEAT, APPLICATION OF........ 35, 47
HEAT, PREVENTING LOSS OF........ 48

JOINTS........ 34, 46

LAMP........ 8

OXIDATION.......... 18
OXIDIZING FLAME.......... 22

PICKLE, SILVERSMITH'S.......... 43
PLUMBAGO.......... 33
PRECIOUS STONES.......... 50

REDUCING FLAME.......... 23

SILVER SOLDER.......... 15, 16
SILVERSMITH'S PICKLE.......... 43
SOLDER, GOLD.......... 17
SOLDER, SILVER.......... 15, 16
SOLDER, HARD ALLOYS.......... 14
SPECIFIC GRAVITY.......... 53
SPELTER.......... 14
STEEL SPRINGS.......... 45
STRUCTURE OF FLAME.......... 21
SWEATING METALS.......... 45

WASH-BOTTLE.......... 10, 11

APPENDIX.

BRAZING STEEL TUBING FOR BICYCLE FRAMES.......... 56, 57

FLUXES FOR SOFT SOLDERING.......... 59, 60

HARD SOLDERING PLATINUM.......... 56
HEATING THE COPPER.......... 60

INVESTING MATERIAL.......... 55

MATS TO HOLD WORK ON.......... 55

REPAIR OF BICYCLE FRAMES.......... 56, 57
REPAIRING BRITANNIA-WARE, PLATED-WARE, ETC.......... 61, 62
REPAIRING GUNS WITH SOLDER.......... 62, 63
REPAIRING JEWELRY.......... 60, 61

SILVER SOLDER FOR STEEL TUBES.......... 57
SOFT SOLDERING—TOOLS AND APPLIANCES,.......... 58
SOLDERING ALLOYS.......... 64
SOLDERING COPPER, THE.......... 59
STEEL POINT FOR MOUTH BLOW-PIPE.......... 55

WOOD ALCOHOL.......... 55

POLYPHASE
Electric Currents,

AND

ALTERNATE-CURRENT MOTORS,

BY

SILVANUS P. THOMPSON, D.Sc.

In preparing the lectures for the press a good deal of new matter has been added. No attempt has been made either to preserve the colloquial form of the discourses or to give to them any pretence to literary style. They are put together in their present shape for the use of students and engineers, and introductory matter has been added to make the relations of polyphase currents to ordinary single-phase currents more clear.

No apology is needed for devoting special attention at the present time to the subject of polyphase electric currents. There seems to be no doubt that in the problem of the electric transmission of power a very important part will, in the future, be played by alternating currents combined in systems of two or three different phases. Already a number of examples exist; and some very large works are now in course of construction. The undoubted advantages possessed by polyphase systems over either *(a)* continuous current systems, or *(b)* ordinary single-phase alternate currents, for the special service of power transmission, are beyond question; but it remains to be seen how far the complications thereby inevitably introduced are, in practice, sufficiently great to militate against polyphase distribution for the purpose of general electric lighting supplies.

In these pages the subject will be dealt with under the following subdivisions:—Generators for Polyphase Currents; the Properties of the Rotatory Magnetic Field, with some account of its historical development; the Theory, Construction and Performance of Polyphase Motors; the Theory and Construction of Motors operated by ordinary single-phase Alternate Currents; together with some account of Polyphase Transformers, and of the measurement of power in polyphase systems.

CONTENTS OF CHAPTERS.

Chapter I.—Polyphase generators. II.—Combinations of polyphase currents. III.—Properties of rotating magnetic fields. IV.—Early development of rotatory-field motors. V.—Structure of polyphase motors. VI.—Elementary theory of polyphase motors. VII.—Analytical theory of polyphase motors. VIII.—Monophase motors. IX.—Miscellaneous alternate current motors. X.—Polyphase transformers. XI.—Measurement of polyphase power. XII.—Notes on design of polyphase motors. XIII.—Mechanical performance of polyphase motors. XIV.—Some examples of modern polyphase motors. XV.—Distribution of polyphase currents from central stations. Index.

FOLDING PLATES TO SCALE.

I.—Two-phase Alternate Current Motor, 6 H.P., 1200 revolutions pe minute. System, C. E. L. Brown. Scale, 1 to 4.

II.—Three-phase Alternate Current Motor, 100 H.P., 5,000 volts, 60 revolutions. Scale, 1 to 10.

ILLUSTRATIONS IN THE TEXT.

Simple alternate-current generator (single-phase). Westinghouse Co' alternator (single-phase). Sketch of four-pole field. Four-pole fiel developed flat. Alternate-current machine: lap-winding. Ditto: wave winding. Curve of induced electromotive force in an ordinary or single phase alternator. Curve of current lagging behind curve of volts. Trans mission from a simple single-phase alternator to a simple synchronou motor. Gramme alternator. Illustration of two-phase transmission. Tw alternate currents differing by a quarter period. A three-phase generator Three-phase currents differing 60° in phase. Field-magnet of three-phas alternator at Lauffen. Developed diagram of winding of three-phas alternator. Arrangement of windings of three-phase alternators. Sectio of field-magnet. Sketch of field magnet. Polyphase generator of th Oerlikon Co. Westinghouse two-phase generator. Brown's "Umbrella' type of alternator. Three-phase generators at the Power station at Hoch felden (Switzerland). Section of the Niagara 5,000 H.P. generator. On of the Niagara generators. Combination of polyphase currents. Group ing of lamps in a polyphase system. Combination of magnetic fields Deprez's theorum. Arago's spinning disk. Babbage and Herschel' experiment. Slit disks used by Babbage and Herschel. Faraday's dis machine. Eddy-currents in spinning disk. Paths of eddy-currents. Han commutator for imitating three-phase currents. Hand commutator fo producing three-phase currents. Baily's Polyphase Motor. Deprez' apparatus. Ferraris' motor. Borel's motor. Coerper's motor. Nikol Tesla's researches, including a multipolar design, a phase-splitting device and a split-phase motor. Haselwander's motor. Circuits of the Lauffen Frankfort transmission. Dobrowolsky's 100 H.P. three-phase motor Stator and rotor designed by Brown. Eddy-currents induced in a coppe cylinder. Modern short-circuited rotor. Experimental forms used b Brown. Tesla's two-pole field. Tesla's four-pole field. Helios Co. four pole field. Dobrowolsky two-pole field. Wound rotor of the Oerlikon Co Structure of the stator. Monophase motors. Elihu Thomson's motor Polyphase transformers. Three-phase transformer constructed by Siemen and Halske. Dobrowolsky's starting-resistance. Kolben's starting-gear fo monophase motor. Brown's starting-gear. Pole high-pressure three-phas motor. Brown's two-phase motor of 120 H.P. Brown's slow-speed two phase motor of 100 H.P. Stator of Brown's slow-speed two-phase motor.

APPENDIX I.—Bibliography of Polyphase Currents and Rotatory-Fiel Motors. (Books and Articles.)

APPENDIX II.—Schedule of some British Patents Bearing on Polyphas and Alternate-Current Motors.

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The topics treated are very many, and minute details are given as to manipulation, and manufacture of materials that cannot be easily obtained in stores. *Builder and Woodworker.*

We cannot enumerate the heads of chapters, but it is safe to say to the reader that he will find in this series, reliable information upon every process known to the Arts in use at the present day. *Mechanical Engineer.*

SECOND EDITION, REVISED AND BROUGHT UP TO 1895.

CONTENTS.

WORKSHOP RECEIPTS, FIRST SERIES.

Alloys: Aluminum bronze, Babbit's attrition metal, brass, brightening and coloring brass, Britannia metal, bronze, bullet metal, Chinese silver, cock metal, gongs, German silver, artificial gold, gun metal, journal boxes, impressions, medals, muntz metal, ormolu, pinchbeck, pipemetal for organs, Queen's metal, rivet metal, imitation silver, speculum metal, statuary metal, sterotype metal, tinning, tombac, tutania, type metal, white metal.

Alcohol Barrels. **Amber:** Working, mending.

Aquafortis: Aqua-regia, blacking.

Bleaching: Ivory, lace, paper, prints and printed books, silk, wool.

Boiler Incrustations: 13 remedies to prevent incrustation.

Book Binding: Tools, pressing, sewing, cutting, ornamenting, headbanding, casing, finishing, lettering, polishing edges of leaves, binding without tools, marbling paper and book edges, tools, colors, patterns.

Bronzing: Brass work, copper utensils, electrotypes, gas fittings, iron, paper, plaster, wood.

Bronzing Powders: Bronzing gun-barrels. **Cameo Cutting.**

Candle-making: Animal fat, tallow boiling, clarifying tallow, ozokerit, wicks, dips, moulds, composite and transparent candles, diaphane, snuffless wicks. **Catgut Making.**

Cements: Acid proof, aqu arium, architectural, jewelers', Chinese, cutlers', elastic, chemical, engineers', fire proof and water proof, fire lutes, glue, liquid, marine, portable, gums, mucilage, artificial gum, impervious, indianite, iron pots and pans, iron railings, iron rust joints, ivory or mother-of-pearl, jet, leather, marble, meershaum, glass and wood, parchment paper, book-binders' paste, plumbers' cement, prints, rubber, stonemasons', turners' cement for filling wood cracks, wood vessels. Using cements.

Cleansing: Alabaster, copper, brass inlaid work, engravings, hands, hats, jewelry, marble, metals, pearls, pictures, plate, silver, steel.

Crayons: Direction for making fourteen colors of crayons, crayons for drawing on glass.

Drawings: Paper, mounting drawings, fastening paper on board, cutting pencils, erasing errors, instruments, board, pens, rule, dividers, pencilling, finishing, lettering, borders, Indian ink, colors, shading, cutting and using stencil plates, frames, vegetable parchment, indelible pencils, mounting engravings, renewing manuscripts, traceing and transfer paper, copying drawings to scale.

Dyeing: Mordants, cotton, black, blue, (five shades), brown (four shades), drab, fawn, green (two shades), lavender (two shades), lilac, pink, red (ten shades), stone, yellow (four shades), cotton spirits. SILK: 31 shades, ammonia paste, indigo, silk spirits, muriate of tin. WOOLEN: 38 shades, woolen spirits, ash vat.

Engraving: Copper, copper plate, gold and silver, lithography, ink, stones, chalk, transfer paper, transfering, drawing on stone, steel. WOOD: Engravers' lamp, tools, preparing gravers and tint tools, holding graver, woods, drawing on the block, proofs, plugging.

Etching: Ground, dabber, oil-rubber, rotten-stone, smoking taper,

bordering wax, engraver's shade, hand rest, stopping out varnish, turpentine varnish, aquafortis, tracing and tracing paper, transferring paper, testing the ground, heating the plate for ground, smoking the plate, transferring, etching, bordering, biting in, second biting, cleaning off, dry point re-biting, re-etching, process avoiding stopping-out, general instructions.

Aqua-tint Engraving: Ground, testing, spirits, trial of ground, laying ground, stopping out the lights, touching stuff, ground to etch on, general instructions, rosin ground engraving, Hamerton's processes, etc.

Fireworks: Full directions for making rockets, pyrotechnic and rocket stars, golden rain, port fires, roman candles, touch-paper, quick-match, gerbes and jets of fire, lances, colored lights, tourbillions, drawing-room fireworks, fire-balloons, serpents, fire-showers, pin-wheels, crackers, colored fires, Pharoah's serpents.

Floor-cloth. Fluxes. Fulminates. Guncotton. Gunpowder.

Glass: Full direction of processes involved in its manufacture.

Graining: Grounds, colors, styles, graining roller, overgraining, marbling, a very full article.

Iron and Steel Tempering: Case hardening. tools, malleable iron, softening cast-iron and files, tempering cast steel, mill picks, springs.

Ivory: Artificial, defects in, flexible, mounting, preparing for paint.

Lathing and Plastering: Lathing, laying, coarse stuff, fine stuff, setting, floating, bastard and trowelled stucco, ceilings, pugging.

Marble Working: Polishing, mounting, selecting, veneering, on wood, metals, zinc and boxes, sculpture by acids, mastics for repairs, stuccoes, wax varnish to preserve statues, coloring, cleansing and repairing marble.

Enameling Slate. Mother-of-Pearl and its applications.

Nitro-glycerine: Dynamite.

Painting: Fresco, glass, oil colors (a number of valuable hints to Artists), plaster, sign boards, transparent painting on linen and paper, water colors, wirework zinc.

Paper: Enamelled, incombustible, ivory, lithographic transfer, manifold writing, powder, stains for paper.

Paper Hanging. Papier Mache. Parchment.

Pavements: Asphalt, tar and concrete.

Photography: A valuable illustrated article of over 100 pages, describing all modern processes and developments of the art.

Plating: An article occupying more than 120 pages, giving careful and detailed descriptions of all processes involved, dipping articles of copper and its alloys, cleansing all the metals before placing in the plating solution, use of scratch brush, battries (a long discription of various kinds used), and valuable data concerning baths, etc., used in obtaining deposits of antimony, bismuth, brass, cobalt, copper, gold, iridium, iron and steel, lead, mercury, nickel, palladium, platinum, silver, tin, and quick deposits of metal on various material.

Polishing: Powders, wheels, burnishing, French polishing, fretwork, horn and ivory, polishing in the lathe, metals, mother-of-pearl, plaster casts, shells, slate and vulcanite.

Pottery: Bodies, colored clays, colors under glaze, enamels and fluxes, glazes, printing oil and stains for pottery.

Printer's Rollers. Recovering Waste Metal.

Rubber: Ebonite and vulcanite. **Rust:** Prevention of, etc.

CONTENTS.

WORKSHOP RECEIPTS, SECOND SERIES.

Acidimetry and Alkalimetry: ready means of estimating the acidity and alkalinity of liquids.

Albumen: occurrence, characters, composition, impurities, qualities, uses, coagulation, restoration to coagulable state; full details of manufacture of Blood albumen, Egg albumen, Fish albumen, and Vegetable albumen, with suggestions as to new sources.

Alcohol: sources; synopsis of manufacture of Caustic alcohol (sodium ethylate), and alcohol from Fruit, Grain, Molasses, Moss, and Roots; rectification; and Wood alcohol (pyroxylic spirit).

Alkaloids: general methods of preparation; special methods for Aconitine, Atropine, Berberine, Brucine, Calumbine, Cascarilline, Colchicine, Morphine, Narcotine, Nicotine, Piperine, Quinine (including amorphous quinine and quinetum), Salicine, Strychnine, and Veratrine.

Baking-powders: general remarks on true value and essential conditions, and many recipes for their preparation.

Bitters: recipes for Amazon, Angostura, Aromatic, Boker's, Brandy, Essence, French Cognac, Hamburg, Nonpareil, Orange, Peruvian, Spanish, Stomach, Stoughton, and Wild Cherry bitters.

Bleaching: recipes for bleaching and decolorizing Albumen, Animal fibres, Coral, Cotton, Esparto, Feathers, Guttapercha, Hair, Ivory, Jute, Linen, Oils and Fats, Paper pulp, Paraffin, Rags, Shellac, Silk, Silver dials, Sponge, Starch, Straw, Wax, Wool.

Boiler Incrustations: numerous analyses of feed waters from rivers, lakes, wells, town supply, rain, canals, pits, springs, and the sea, with analyses of the incrustations produced by them, and a critical examination of the various chemical, chemico-mechanical and physical processes for preventing boiler corrosion.

Cements and Lutes: general directions for the preparation and application of cements and lutes; numerous recipes under the following heads,—Acidproof, Alabaster, Algerian, Almond paste, Amber, Aquarium, Architectural, Armenian or Diamond, Badigeon, Bottle, Brimstone, Buckland's, Canada balsam, Cap, Casein, Chemical, Chinese glue, Chrome, Coppersmiths', Corks, Crucible, Curd, Cutlers', Dextrine, Egg, Elastic, Engineers', Fat, Fireproof, French, Glass, Glass to Metals, Glue (including Fish glue, Lapland glue, Liquid glue, Mouth or Lip glue, Portable glue), Glycerine, Gum Arabic, Gum tragacanth, Hensler's, Indiarubber, Iron, Isinglass, Ivory, Japanese, Jewellers', Kerosene lamps, Labels, Laboratory, Lead, Leather, Mahogany, Marble, Marine glue, Masons', Meerschaum, Metal to glass, stone, etc., Microscopical, Milk, Naturalists', Opticians', Parabolic, Parian, Paris, Paste, Peasley, Plasters, Plumbers', Porcelain, Putty, Sealing-wax, Shellac, Soluble glass, Sorel's, Steam, Stone. Turners', Waterproof, Wollaston's, Wood, Zeiodelite.

Cleansing: a complete selection of recipes for washing, cleaning, scouring, purifying, and removing stains, arranged under the following heads,—Brass, Bronze, Casks, Celluloid, Chip bonnets, Coins, Copper vessels, Druggists' utensils, Engravings, Feathers, Fire-arms, Floors, Fur, Gas chandeliers, Gilt mountings, Gilt picture frames, Glass (bottles, globes, plates, slides, paint stains, windows), Gloves, Gold, Iron and Steel, Ivory and Bones, Leather, Marble, Mirrors, Oilcloth, Paint, Paintbrushes,

Paintings, Parchment, Sheepskin mats, Silver, Sponge, Stains removing (aniline, fruit and wine, grease and oil, ink and ironmould, lime and lyes, mildew, milk and coffee, paint and varnish, stearin, tannin, tar and axle-grease), Stills, Stones, Stuffed animals, Teapot, Textile fabrics (English and French cleaning and scouring, cleaning with benzine, apparatus used, methods of operation for ancient tapestry, carpets, cloth, curtains, and bed furniture, dresses, flannel, hearthrugs, lace, shawls and scarves, sheepskin rugs and mats, silk goods, table covers), Tobacco pipes, Vellum, Violins, Violin bows, Wall papers, Zinc vessels.

Confectionery: the confectioners' stove, clarification of sugar, boiling degrees of sugar; methods of making Cakes (Bordeaux, pound, Italian bread, Savoy, wafers), Candied sugar (chain, crystallized chocolate, crystallized fruits, liqueur rings), Candy (artificial fruit and eggs, burnt almonds, coconut ice, coltsfoot candy, filberts and pistachios, ginger candy, lemon prawlings, orange prawlings, peppermint, lemon and rose candy, plum candy, sweetflag candy), Chocolate (roasting, making, drops, harlequin pistachios, cinnamon, mace, clove, stomachic, and vanilla chocolate), .Comfits (almond, barberry, caraway, cardamom, celery, cherry, cinnamon, clove, colouring, corainder, flavoured with liqueurs, ginger, lemon peel or angelica, nonpareils, orange, raspberry), Crack, and Caramel (acid drops and sticks, almond hardbake, almond rock, barley sugar drops and tablets, brandy balls, clove, ginger, or peppermint rock, extracting the acid from candied drops, nogat, raspberry rock or sticks, spinning, almond baskets, Chantilly baskets, gold web, grape, orange or cherry baskets, raspberry rock, rock sugar, silver web) Drops (catechu, chocolate, cinnamon, clove, coffee, ginger, lemon, orange-flower, orgeat, peppermint raspberry, rose, vanilla, violet), Ices (apparatus, freezing, almond or orgeat ice cream, apple water ice, apricot water ice, barberry, biscuit cream, brown bread ice, burnt almond ice cream, burnt ice cream, cherry water ice, chestnut ice, chocolate ice, coffee ice cream, cream ice, currant ice, currant water ice, custard for ices, custard ices, damson ice, filbert ice cream, ginger ice, gooseberry water ice, lemon ice cream, lemon water ice, liqueur cream ice, liqueur water ice, millefruit ice cream, millefruit water ice, noyau cream ice, orange ice cream, orange water ice, peach ice, peach water ice, pineapple ice, pineapple water ice, pistachio ice cream, punch water ice, raspberry ice, raspberry water ice, ratafia cream, Roman punch ice, strawberry ice, strawberry water ice, Swiss pudding, tea ice, vanilla ice), Lozenges (bath pipe, brilliants, catechu, cinnamon, clove, coltsfoot, ementine, ginger, ipecacuanha, lavender, magnesia, marshmallow, nitre, nutmeg, patta rosa, peppermint, refined liquorice, rhubarb, rose, saffron, sponge, steel, sulphur, tolu, vanilla, worm, yellow pectoral, zinc).

Copying: obtaining copies of printed and written matters by Chemical methods (including cyanotype or ferro-prussiate paper, cyanoferric or gommoferric paper, Joltrain's, Beneden's, Dietrich's, autoscopic, Tilhet's, Zuccato's, Pumphrey's, Waterlow's, hectograph or chromograph, Magne's, Willis's, Poitevin's, Woodbury's, photo-lithographic, Niepee's, Ehrard's, Fox Talbot's, Scamoni's, Nuth's, phototypy, Michaud's, chromotype, Lenoir's, Warnerke's, Edwards' heliotype, Waterhouse's, Alissoff's polygraphic, Asser's, Komaromy's, and numerous other processes); by Mechanical methods (embracing stencils of various kinds, tracing on cloth, tracing-cloth, and other recipes), Copying Pencils; Transferring (photographs to wood, engravings to paper, transfer process on glass).

Disinfectants: the preparation and characters of all the substances hitherto proposed as deodorizers, disinfectants, or antiseptics, with comparative tables of results according to different authorities, and discussions

on the advantages and disadvantages of the disinfectants now before the public.

Dyeing, Staining, and Colouring: containing a most comprehensive collection of new and approved recipes, under the following heads—Calico-printing, in chrome standard, discharge style (blacks, blues, whites, yellows), indigo effects (direct indigo blues, lapis resists, combined indigo and madder effects, white reserves, white resists, orange reserves, yellow reserves, blues, and white, red, green and yellow, green, and yellow discharges on vat-blues), madder colours (blacks, browns, chocolate, drab, purples, reds, whites), manganese bronze style, padding style, pigment style, plate style, reserve style, spirit colour style (blues, browns, chocolate, greens, pinks, purples, reds, yellows), steam colours (amber, blacks, blues, browns, buff, chocolates, cinnamon, drab, greens, greys, lavender, lilac, orange, pinks, purples, reds, violets, yellows); China grass; Cotton (blacks, blues, browns, chocolate, claret, drabs, greens, greys, olive, oranges, purples, reds, violets, yellows); Encaustic colours; Feathers; Flowers, Grasses, and Mosses; Hats (beaver, cream, fawn, mouse, rose, slate, cinnamon); Horn (blacks, greens, purples, red, tortoiseshell, yellow); Horsehair (blue, brown, red); Ivory (blacks, blues, browns, greens, reds, yellows), vegetable ivory; Kid gloves (blacks, browns, Russia red, grey, violet, yellow); Leather (blacks, blues, browns, russets, reds, yellows, greens, violets, purples, crimson); Metals (brass, bronze, gold, gun-metal, iron and steel, silver, zinc); Paper (ambers, blues, browns, buffs, chocolates, crowfoot, fawns, greens, greys, lilacs, Nankeen tissue, olives, oranges, pinks, reds, roses, skin colour, straw tint, violet, white tissue, yellows); Parchment; Silk (blues, greens, magentas, maroons, pansy, scarlets, violets, yellows); Straw; Whitewashing, calcimining, or distemper; Wine; Wood (blacks, blackboard washes, blues, browns, ebonizing, floors, greens, greys, mahogany, oaks, purples, reds, satinwood, violet, walnut, yellows); Wool (amaranth, blacks, blues, greens, grenades, greys, maroons, olives, oranges, ponceau, puce, reds, violets, wood-colour).

Essences: Aconite, Allspice, Almonds, Ammoniacum, Anchovy, Angelica, Aniseed, Anodyne, Antihysteric, Aromatic, Bark, Beef, Bitter, Camphor, Caraway, Cardamon, Cascarilla, Cassia, Cayenne, Celery, Chamomile, Cinnamon, Cloves, Cochineal, Coffee, Coltsfoot, Cubebs, Dill, Ergot, Fennel, Fruit (artificial, including apple, apricot, banana, blackberry, black cherry, cherry, currant, grape, lemon, melon, nectarine, orange, peach, pear, pineapple, plum, raspberry, strawberry), Ginger, Guaiacum, Headache, Hop, Lemon, Lemon-peel, Lovage, Nutmeg, Orange, Orange-peel, Pennyroyal, Peppermint, Quassia, Quinine, Rennet, Rhubarb, Royale, Sarsaparilla, Savory Spices, Soap, Soup Herbs, Spruce, Turtle, Water Fennel, Westphalian, Wormwood.

Extracts: preparation; Aconite, Aloes, Angelica, Apples, Belladonna, Buchu, Cainca, Calabar Bean, Calumba, Cherry (Wild), Cinchono, Colchicum, Colocynth, Cotton-root, Cubebs, Ergot, Gentian, Golden Seal, Hellebore, Hops, Jaborandi, Jalap, Juniper, Lactucarium, Lettuce, Lobelia, Logwood, Madder, Male Fern, Malt, Meat, Mezereon, Myrrh, Narcotic, Nux Vomica, Opium, Pareira, Pellitory, Pinkroot, Poppies, Quassia, Rhatany, Rhubarb, Sarsaparilla, Scammony, Senna, Smoke, Squills, Stillingia, Stramonium, Taraxacum, Tobacco, Valerian, Wormseed.

Fireproofing: Buildings, Extinguishing Compounds, Textile Fabrics, Timber, Writing Materials.

Gelatine, Glue, and Size: manufacture of glue, manufacture of size, drying glue, composition of glue, Characters of glue, selection of glue, manufacture of gelatine from bones, Rice's gelatine, Cox's sparkling

gelatine, Heuze's gelatine from neats'-foot-oil residues, Nelson's gelatine, comparison of gelatines, preventing nuisance at glue works.

Glycerine: sources, early processes, Price's method, obtaining glycerine from spent lyes of the soapmaker.

Gut: the preparation of gut for fiddle-strings and sausage-skins; silk-worm gut.

Hydrogen peroxide: manufacture and application.

Ink: Black writing, Coloured writing, Copying, Engraving, Indelible, Indian, Invisible or Sympathetic, Marking, Miscellaneous, Printing, and Stamping inks.

Iodine: manufacture from seaweeds, and from caliche.

Iodoform: processes for making.

Isinglass: from fish, and from various kinds of seaweed.

Ivory substitutes: numerous ways of preparing artificial substitutes for ivory, such as celluloid, etc.

Leather: Calf-kid, Chamois leather, Currying, Depilatories or Unhairing, Glove-kid, Imitation leather, Morocco leather, Patent (Japanned or Enamelled) leather, Russia leather.

Luminous bodies: natural phosphorescent substances; artificial luminous paints,—Balmain's, Heaton and Bolas', etc.

Magnesia: new and cheap way of preparing.

Matches: general sketch of manufacture, especially with regard to the ingredients, etc., of igniting compositions; Vestas and Vesuvians.

Paper: selection and assortment of rags; boiling raw materials recipes for high-class papers; washing and breaking; draining and pressing. Astronomical drawing paper, Blotting paper, Crystalline paper, Deciphering burnt documents, Filtering-paper, Hardening paper, Iridescent paper, Lithographic paper, Luminous paper, Oiled paper, Packing-paper, Safety-paper, Smoothing paper, Splitting a sheet of paper, Test-papers, Tracing-paper, Transfer-paper, Waxed paper.

Parchment: preparation of natural parchment, and artificial parchment or parchment paper; removing wrinkles from parchment.

Perchloric acid: cheap mode of making.

Pigments, Paint, and Painting: embracing the preparation of *Pigments*, including alumina lakes, blacks (animal, bone, Frankfort, ivory, lamp, sight, soot), blues, browns, greens, reds, whites,—by American, Dutch, French, German, Kremnitz, and Pattinson processes, precautions in making, and composition of commercial samples,—whiting, Wilkinson's white, zinc white), yellows; *Paint* (vehicles, testing oils, driers, grinding, storing, applying, priming, drying, filling, coats, brushes, surface, water-colours, removing smell, discoloration; miscellaneous paints—cement paint for carton-pierre, copper, gold, iron, lime, silicated, steatite, transparent, tungsten, window, and zinc paints); *Painting* (general instructions, proportions of ingredients, measuring paint work; carriage painting—priming paint, best putty, finishing colour, cause of cracking, mixing the paints, oils, driers, and colours, varnishing, importance of washing vehicles, re-varnishing, how to dry paint: woodwork painting.

Potassium oxalate: new and easy way of making it for photographic purposes,

Preserving: charred paper, food (beer, fish; fruit, grain, and vegetables; honey, meat, milk), fruit-juices, gum, hay, indiarubber, leather, leeches, lemon-juice, Rankin's and Pasteur's fluids, skins and furs, stone, textile fabrics, urine, vaccine lymph, wood.

CONTENTS.

WORKSHOP RECEIPTS, THIRD SERIES.

Alloys: components, general principles for making, how to melt metals, fluxes, fusibility of metals, order of melting ingredients of alloys, table of fusing points, furnaces for melting brass and other alloys, crucibles for melting alloys, casting mixed metals, right moment for pouring, moulding articles in relief, composition for core for difficult jobs. Solders. Miscellaneous alloys (embracing compounds for friction bearings, steam-whistles, cylinders, taps, valve-boxes, pistons, mathematical instruments, rivets, pinchbeck, tombac, electrotypes, bullet metal, pin wire, flute-keys; composition of various Japanese and other bronzes, ancient coins, rings, figures, implements, pins; manufacture and ornamentation of Japanese bronzes; inoxidizable alloys, soft alloy for cold soldering, alloys for small articles, white alloy, alloy for medals and coins, amalgam for coating plastic castings, anti-friction alloys, sterro-metal, bismuth bronze.

Aluminium: properties, manufacture, applications.

Antimony. Barium. Berryllium. Bismuth. Cadmium. Cœsium. Calcium. Cerium. Chromium. Cobalt.

Copper: properties, cleaning ore, crushing, jigging, buddling; dry methods of treating ores—German, English (including furnaces and details of working); wet method; hardening and toughening the metal; common impurities and their influence; characters of pure electrical copper wire; tubes, bending; welding copper.

Electrics: Alarms: examples of house alarms, tell-tales for cisterns and boilers, time signals, and tell-tale clocks, their construction and fixture. Batteries: constitution of a battery; making batteries; zinc plates, forming cylinders, amalgamating with mercury, attaching; negative elements; exciting fluids; separating the elements; containing cells construction, arrangement, cost, peculiarities, and applications of various forms of battery. Bells: the apparatus employed; choice and arrangement of battery, circuit wire, circuit closer and bell; systems of establishing bells. Carbons. Coils, (induction, intensity, resistance). Dynamo-electric machines, principles and methods of construction. Microphones. Motors: principles and practice of construction. Phonograph. Photophone. Storage: the storage and reproduction of electric energy, construction, charging, maintenance, effectiveness and cost. Telephone: principles underlying their action, various forms,—the string telephone, Kennedy's, Thompson's, Gower's, their construction and arrangement, with hints on making calls, augmenting sound, cheap magnets, circuits, transmitter and switch.

Enamels and Glazes: enamelling cloth, leather, metals. Glazing pottery,—composition of the glazes, their preparation and application. Enamelling on wood.

Glass: breaking, coating on metals; colored,—transparent and opaque tinted glass, preparation of the pigments and stains. Engraving, etching, frosting, and gilding. Ornamentation processes on glass,—adding stars, coils of thread, colored casings, metallic plates, grains of colored glass, iridescence, frosting, and etchings in gold leaf on finished glass, eroding glass surfaces, colored photographs on glass, protecting glass surfaces from effects of heating and cooling, roughening glass, spun glass (its production properties and uses,) stoppering glass bottles, writing

on glass—preparing the surface and compounding the writing fluids.

Gold: distribution, modes of occurrence, methods of extraction, amalgamation, refining, properties of gold.

Indium. Iridium.

Iron and Steel: decorating, malleable iron, melting, tempering iron and steel,—effects of hardening, causes of hardening, influence of carbon, influence of temperature, classifying steels, testing steels and irons, hardening and tempering defined, heat tests, heating steel, fuel for heating, quenching, degrees of temper, cracking and splitting, burning, modifications of dipping, annealing, recipes (case-hardening, wrought iron, axle arms, prussiate of potash process, cutters, files, gravers, hammers, lathe mandrel, mill-picks, mining picks, saws, springs, taps and dies, tools generally); welding,—conditions, heating, fluxes, selection of iron, nature of welding, recipes for welding steels, irons, cast iron, spring-plates, etc.

Lacquers and Lacquering: brass, bronze, brunswick black, copper, gold, iron and steel, Japanese and Chinese lacquers.

Lead: sources, the ore-hearth, reverberatory furnaces, blast furnaces, precipitation, slag melting, wet methods of extraction, softening, desilverizing, sheet lead, lead pipe, shot.

Lubricants: friction defined, characteristics of an efficient lubricant, viscosity and gumming of oils, fire-testing mineral oils, flashing-points, igniting-points, and burning-points. Formulæ for lubricants, axle-greases, railway grease, waggon grease.

Magnesium. Manganese. Mercury. Mica. Molybdenum.

Nickel: ores, processes of extraction, treating sulphides, treating arsenides, treating very poor ores worked for other metals, properties and uses of nickel.

Niobium. Osmium. Palladium. Platinum. Potassium. Rhodium. Rubidium. Ruthenium.

Selenium; how found, commercial sources, preparation from native copper-lead selenide, from sulphuric acid chamber and flue deposits where seleniferous sulphur or pyrite is burned, and from the flue-dust of lead desilverizing works, propertes.

Silver: occurrence, ores, extraction by amalgamation processes, extraction by cupellation and eliquation, purification of commercial silver.

Slag; the production of blast furnace slag, its composition, purposes to which it may be applied, including road-metal, castings, paving-blocks, bottle-glass, shingle, sand, cement, mortar, bricks, artificial stone, mineral wool, insulating, manure, and casting-beds. Arrangement of the Cleveland Slag Works, analyses of Finedon, Cleveland, Hematite, Bessemer, Dowlais, and Dudley slags, Portland cement, slag concrete bricks, slag cement, gypsum and puzzolanas.

Sodium. Strontium. Tantalum. Terbium. Thallium. Thorium.

Tin: ores, cleaning and sorting the ore, stamping the ore, calcining the ore, washing the roasted ore, smelting the black tin, refining, utilization of scrap tin, properties and uses.

Titanium. Tungsten. Uranium. Vanadium. Yttrium.

Zinc: ores; extraction of the metal, calcining for oxidation, smelting the oxide by the Belgian, English and Silesian methods.

Zirconium.

Aluminium: discussion of the merits of several newly proposed methods for cheapening the production of the metal.

CONTENTS.

WORKSHOP RECEIPTS, FOURTH SERIES.

Waterproofing:—Rubber Goods; spreading the rubber, recovering naptha from the solution, varnishing fabrics, elastic fabrics. Cuprammonium, zinc-ammonium and similar preparations, Willesden fabrics. Miscellaneous waterproofing preparations.

Packing and Storing: glass and china, deliquescent salts, explosives, flowers, articles of delicate odor.

Embalming: corpses and anatomical specimens.

Leather Polishes: liquid and paste blackings, dubbings, and glosses for harness, boots, and patent leather.

Cooling:—Air; by mechanical means, by evaporation, by ice, by underground channels. Cooling and Freezing Water; by solution of solids, by evaporation of liquids, by expansion of gases. Cooling syrups, solutions, etc.

Pumps and Siphons:—Pumps; pulleys, windlasses, levers, troughs, swapes, bucket wheels, screws, scoops, and pumps for raising water; acid pumps, syrup pumps, soap and lye pumps. Siphons; of glass and metal.

Dessicating: air-ovens, water-ovens.

Distilling: water, tinctures, extracts, camphor, essential oils, flowers.

Emulsifying: pharmaceutical and photographic emulsions.

Evaporating: general principles; saline solutions, saccharine liquors, glycerine. Acids,—in leaden, glass and platinum vessels.

Filtering:—Water: by using gravel and sand, charcoal, iron, magnesia, porous pottery, cellulose, and sponge as filtering media; filtering cisterns. Laboratory filters for pharmaceutical, chemical, photographic and other purposes. Filters for liquids demanding special conditions: gelatinous fluids, liquids affected by air, lime muds from soda causticisers, syrups and oils.

Percolation: macerating and filtering by displacement.

Electrotyping; apparatus and fittings, preparing the form, preparing the moulding pan, blackleading, stopping out, the deposit, trimming and bevelling, mounting, picking.

Stereotyping:—Plaster process; apparatus, preparing the metal, preparing the form, casting the plate, cooling the cast, knocking-out the plate, flattening the plate, turning to uniform thickness, planing the back, bevelling and squaring, mounting, perfecting. Paper Process; supplementary remarks.

Bookbinding: folding, beating and rolling, collating, marking up and sawing in; sewing, forwarding, pasting up, pasting on the end papers, trimming, gluing up, rounding, backing, millboards, drawing in and pressing, cutting, coloring the edges, gilt edges, head banding, covering, pasting down, hand-finishing, blocking, calf colouring.

Straw-plait, Matting, and Basket-making.

Musical Instruments:—Pianos: selecting, putting in a string, repairing sticker-hinge, re-hinging levers, centers sticking, keys sticking, blocking, taking to pieces, keys, hammer sticking, pitch, buzzing, faulty repetition, renewing pins and wires, rusty wires, Celeste pedal. Harmoniums: the case, feeders, valve-boards, feeder-folds, wind-trunks, reservoir, foot-boards, wind-chest. Musical Boxes.

Clock and Watch Mending:—Clocks:—eight-day, thirty-hour

English, spring, musical, outdoor, drum, bird, American, German, French. Watches: repairing and cleaning, fitting dials, timing watches.

Photography: Gelatine processes, the gelatine, emulsions, developers, intensifiers, stripping film from negatives, remedy for frilling, putting up plates, reducing negatives, toning silver citro-chloride prints and transparent positives, drying plates, gelatino-bromide film paper, tissue negatives from plates. Collodion processes: collodio-citro-chloride emulsion, collodio-chloride paper, example of collodion process, fixing silver prints without hyposulphite, permanent silver prints, transparencies, collodion formula, saturated iron solution, iron developers, collodio-chloride printing process, intensifying solution for wet-plate negatives, developer for very delicate transparencies, durable sensitised paper, Werge's gold toning bath, lime toning bath, collodion enlargements. Albumen processes: albumenising paper, floating albumenised paper on the silver bath, silver printing on albumenised paper, lantern slides on albumen, glazing albumenised prints. Miscellaneous, stripping films, restoring faded photographs, printing a positive from a positive, reducing over-printed proofs, photographing by magnesium Light, paper negatives, photographing paper photographs, a photographic print upon paper in five minutes, paper negatives, enlarging on argentic paper and opals, light for the dark room, mounting prints, paper pan, testing a lens, photographing on wood, silver prints mounted on glass, medallions, vitrified photographs, enamel photographs, toning, out-door photography, negative, bath, varnishes, preparing sulphurous acid, instantaneous shutter, arranging drop-shutters for a variety of lenses, measurement of speed of drop-shutters, instantaneous shutter for timed exposures, making photographic exposures in the dark room, dry-plate holder and exposing case, camera attachment for paper negatives, apparatus for instantaneous photography.

Index and General Index to Series I to IV

Each Series possesses its own special value, and the utility of the four volumes has been completed by furnishing the fourth with a General Index to the whole set. From the great range of subjects dealt with and the facility thus afforded for reference, the four series of 'Workshop Receipts' may be said to constitute in themselves a well-stored library of technical information such as no other publication affords. The descriptions and instructions are given in plain language, aided by diagrams where necessary; technicalities are explained, and every care has been taken to check the quantities, and to make the index a real guide to the contents.